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THE SPECIFICATIONS FOR A NEW WATER SUPPLY for Hoboken, under which bids are to be received April 30, as noted briefly in our issue of April 15, contain the following provisions: Water must be delivered into the distribution mains so as to give 40 lbs. pressure on a gage 32 ft. above mean high water. Reservoir capacity of 50,000,000 gallons must be provided within five miles of the city limits, and two conduits capable of delivering 12,000,000 gallons each, daily, at the required pressure, must be constructed from the reservoir or reservoirs to the city limits. An initial consumption of 4,000,000 gallons per day, with a yearly increase of 4%, will be assumed as a basis for comparing bids, and the city will agree to pay for at least 4,000,000 gallons daily from the start. Bids must be accompanied with descriptions of the proposed supply and a certified National bank check for $50,000. The successful bidder must execute a bond for $250,000, to be renewed at the end of each five years during the contract. Prices must be quoted per million gallons at which water will be delivered at the city limits for periods of 15, 20 and 25 years, and bidders may, but are not obliged to, state at what price the city shall have the option to buy the works at the end of 5, 10, 15 and 20 years, upon giving one year's notice. The specifications were adopted April 9, and the bids are to be received on April 30, just three weeks later, thus giving but a short time for the preparation of plans and estimates. Mr. Henry Lohmann, Jr., is Water Registrar.

A WATER PURIFICATION PLANT FOR BALTIMORE has been recommended for consideration by the Committee on Water, of which Mr. C. E. Cunningham is Secretary. The committee suggests that a special committee be appointed to take up the matter.

LOW BIDS FOR ASPHALT PAVING were received in Brooklyn, N. Y., on April 15, the lowest for the work in five of the streets being that of the Eastern Bermudez Co., at 90 cts. per sq. yd. for asphalt, 70 cts. per lin. ft. for new curb, 30 cts. for old curb, $4 a cu. yd. for concrete and 5 cts. per sq. ft. for flagging; total, $27,252. Mr. N. P. Lewis is the Engineer in Charge of Street Construction and Maintenance.

A PIECE OF RAPID RAILWAY BUILDING was done by the Buffalo, Tonawanda & Niagara Falls Electric Ry. Co., which built an extension of its line, one-quarter mile long, in the night of April 18, so far as the laying of the track and pushing a single car over it were concerned. The cause of this hasty work was the incorporation, on April 12, of the Buffalo, Niagara River & Grand Island Ry. Co., with a right to build an electric railway from the foot of Tonawanda St., Buffalo, along O'Neill St. to the upper Grand Island Ferry. The older company also wanted O'Neill St., for its own uses, as a profitable short line to the ferry, and it took the course outlined above.

THE CONTINUATION OF THE 1½% TAX FOR THE Chicago Drainage Canal, which was asked by the Board of Trustees of the canal at the opening of the recent session of the Illinois state legislature (Eng. News, Jan. 7, 1897) and which has been the cause of no little wrangling among the trustees as well as dispute with the various Illinois Valley cities, will probably be secured without further delay. At a recent conference of the representatives of the canal and valley interests, a joint bill was agreed upon which grants the increased tax and also embodies several provisions desired by the valley towns. Of these provisions the one to be noticed most particularly is that preventing the construction of any but movable bridges across the channel, although such bridges are not to be maintained and operated as movable bridges for a period of seven years, unless the needs of navigation on the Desplaines and Illinois rivers, when connected with the channel, shall demand their operation.

THE INSTITUTION OF CIVIL ENGINEERS, according to the late presidential address of Mr. John Wolfe Barry, C. B., had, in 1836, a total membership of 238 and a total income of $3,565 per year. At the present time the membership of all classes numbers about 6,000—and nearly 7,000 if the Students are included. The present ordinary annual income is about $125,000, and the Institution holds property valued at $500,000, including the freehold of the premises upon which the Society House stands. The Institution of Civil Engineers, while practically founded in 1821, was incorporated by Royal Charter in 1828, under Thomas Telford as President. At the present date applications to the Council for admission into the Institution average 350 annually. Mr. Barry also called attention to the fact that Mr. James Forrest, now Honorary Secretary, had been connected with the Institution for 54 years, and he had been Assistant Secretary or Secretary for 40 years. He had personally known all the Presidents, with the exception of Telford, and much of the present prosperity of the Institution, said Mr. Barry, was due to the sagacity and devotion of Mr. Forrest.

EXPERIMENTS ON THE BURSTING OF SMALL FLY-wheels are being conducted at the Case School of Applied Science, Cleveland, O., by two students of the senior class to obtain data for their thesis. The first wheel tested was 15¼ ins. diameter. It burst at a speed of 6,525 revolutions per minute, or a rim speed of over five miles a minute. The wheel was driven by a steam turbine, and the speed was determined by observing the tone. A timber bombproof, so-called, was built around the wheel, but it was entirely demolished. One piece of the rim shot through 4 ins. of pine and 2½ ins. into the hard wood floor, cutting its way like a bullet.

RAILWAY ACCIDENTS DURING THE PAST WEEK were few and of trifling importance, causing no loss of life, so far as the press dispatches show.

AN EXPLOSION OF CINDER caused the serious burning of five men, two of them possibly fatally, at the Republic Iron Works, Pittsburg, on April 15. The accident is one that is quite common in iron works, and is nearly always due to carelessness of the workmen. The cinder run out of a tap hole of a puddling or heating furnace, is caught in a small cast iron tub on wheels, called a "buggy," and while still in a melted condition is wheeled out and dumped on a pile. If the spot where it is dumped is quite dry no accident can occur, but if there is a pool of water or even moist earth present an explosion may take place which may drive the melted cinder 50 ft. or more, endangering the lives of every one within striking distance.

THE MISSISSIPPI RIVER FLOOD appears to have passed its point of greatest danger. The river is now falling at the rate of a foot a day at Cairo and more slowly at Memphis. At Natchez it is stationary. Several crevasses have been made in the levees in Northern Louisiana during the week, and the plantations in Concordia, Tensas and Madison parishes are being rapidly flooded. In Madison parish 30,000 acres of cultivable land are now reported under water. Work in strengthening the levees is being continued throughout Louisiana.

THE FIRST CAISSON FOR THE NEW YORK TOWER of the new East River bridge will be launched, it is expected, about May 1. There will be two caissons for this tower, and the one to be launched is that for the north half of the masonry. It is 76 ft. long, 60 ft. wide, and 19 ft. deep, and will be sunk in about 20 ft. of water. The twin caisson for the south half of the tower will not be begun until the launching of the first is completed.

A THREE-HINGED BETON ARCH-BRIDGE has been built over the Danube, at Inzigkofen, in the Principality of Hohenzollern. It was constructed in 1896 to replace a wooden bridge carried away by a flood in 1893. This new bridge has a span of 141 ft., and a rise of 14.36 ft. above the bottom hinges. The beton foundation starts from the rock on one side and from a 20 ft. bed of hard gravel on the other side. The width of the bridge, between parapets, is only 12.46 ft., allowing for a single driveway and two 2-ft. footways. Cast-iron hinges were used at the spring and at the center of the arch, to provide against the danger from rupture when the centers were struck and against movement due to variations of temperature. The centers were supported on sand boxes resting upon clumps of piles, and the beton was from 3.28 to 4.26 ft. thick, perpendicular to the line of pressure, deposited in thin layers and divided into voussoirs with a width about equal to the thickness of the arch. Upon striking the centers the arch sank only 0.3-in. at the crown and the bridge was finally tested by passing over it a road roller weighing 7,700 lbs. The whole bridge was built in four months, of which 2½ months were consumed in depositing the beton, and the total cost of the structure was $6,650, with a total volume of 824 cu. yds. of beton and masonry. This bridge is fully described and illustrated in "Le Genie Civil" for April 3, 1897.

THE FIRST METALLIC BRIDGES, says Mr. Mehrten in "Stahl and Eisen," appear to have been of Italian origin and they date back to the sixteenth century, so far as the idea is concerned. But the Coalbrookdale bridge, built in 1776-79, over the Severn, in England, was the first realization of this idea. The first metallic bridge erected upon the Continent was constructed in 1796, at Laasan, in Silesia, and consisted of a cast-iron arch of 39.36 ft. span. The first cast-iron bridge in France was the Austerlitz bridge over the Seine, in Paris, commenced in 1801 and finished in 1806. The "Pont des Arts," also over the Seine, was commenced in 1804.

THE BILLS BEFORE THE NEBRASKA LEGISLATURE, proposing to create a "Board of Civil Engineers," upon which there were to be no engineers, and substituting a lawyer for the engineer in the State Board of Irrigation, have both been defeated, thanks mainly to the efforts of the Governor of Nebraska. This proposed legislation was commented upon in our issue of Feb. 25 and March 11, of the current volume.

THE HARLEM KILL CANAL BILL, presented to the Senate by Senator Platt, is not approved of by the U. S. Engineer officers. The bill would require the Secretary of War to contract with Charles Stoughton, of New York, for the constructing of a canal connecting the Harlem River with the East River and Long Island Sound, at Port Morris. The bill is based upon a preliminary report of Gen. John Newton, made in 1881, and calls for a canal 3,400 ft. long, 300 ft. wide and 15 ft. deep, with a cost estimated by Gen. Newton at $2,204,406, but limited to a cost of $1,296,000 in the bill. The engineer officers object to the bill because Mr. Stoughton has no technical knowledge of such work and his estimate is lacking in detail. The canal may cost from $1,000,000 to $5,000,000, according to the material found. The government possesses a plant for works of this character superior to that of any outside contractor, and can perform the work more cheaply and rapidly, says Col. G. L. Gillespie, and if the canal is really wanted all that is required is for Congress to make the necessary appropriation.

THE BOWERS DREDGE PATENTS may be used by the City of Portland, Ore., for $10,000 for their lifetime, according to a late proposition made by the Bowers Company. But while the city may equip its dredges with these patents for dredging in the Willamette and Columbia rivers, and deposit the material on the banks, it is prohibited from entering into any contracts or arrangements for filling land.

ANOTHER ARCTIC EXPEDITION is being planned by Robert E. Peary, C. E., U. S. N., according to the representations made to induce the Navy Department to rescind the late order detailing Mr. Peary to duty at the Mare Island Yard, California. Mr. Peary's plan, as now given out, is to purchase and load a ship with concentrated provisions; to proceed to Whale Sound and with the assistance of Eskimos land the stores at Sherard Osborne Fjord, or further north, if possible. The ship is then to be sent home and as soon as the fjords freeze over sufficiently to permit sledge travel, the supplies would be advanced and cached in a line toward the Pole. He would expect, in the following spring, to find his small party and the bulk of the provisions at the northern terminus of the North Greenland Archipelago, probably near the 85th parallel, with a line of food-caches extending to the starting point. From this point, and as the weather permitted, he would make a dash for the Pole, with two of the best Eskimos, picked dogs and the lightest possible equipment. No definite time of departure is fixed, as all the preliminary arrangements are not yet completed. But Mr. Peary expects to visit Greenland this summer, and there organize a force of Eskimos for the intended expedition and otherwise make preparations. He will also endeavor to bring back the 100-ton meteorite found by him in Greenland.

CIVIL SERVICE EXAMINATIONS OF CANDIDATES for the Department of Public Works, New York city, are announced as follows: April 23, assistant civil engineer and instrument maker; May 10, hydrographer. Applications are also desired for the position of expert instrument maker. Mr. S. William Briscoe is Secretary of the Civil Service Commission, with offices at the new Criminal Court Building.

A $12,000,000 CONTRACT for public improvements in Havana, Cuba, has been secured by Mr. Michael J. Dady, of 40 Court St., Brooklyn, the exact figures being $11,889,251. The work includes the paving of 72 miles of streets with granite, asphalt and Belgian blocks; over 100 miles of vitrified brick and cast-iron sewers; and a contract for a canal some seven miles long, 60 ft. wide and 8 ft. deep, to make a current in the harbor. The work will be begun in November next and must be completed within five years.

THE FLOODS OF THE MISSISSIPPI RIVER.†

By Wm. Starling,* M. Am. Soc. C. E.

The great valley, or drainage basin, of the Mississippi has been described as an immense plain, extending from the Alleghanies to the Rocky Mountains, and limited on the north by the Saskatchewan or Winnipeg and the Saint Lawrence systems. On the south, it is contracted to rather narrow dimensions, namely, between the Tombigbee and Pearl Rivers drainage of the east and the Sabine River on the west. More accurately, the plain itself may be defined as consisting of two slopes, extending, respectively, from the foot of each of the mountain ranges, and intersecting in a line which is approximately marked by the course of the Upper Mississippi and the great trunk of the Lower Mississippi. Taking a section along the 41st parallel of latitude, the lowest point is found on the Illinois River, about 75 miles east of the Mississippi. From this point, in both directions, there is a gradual rise to the bases of the mountains on the east and west.

Geologically, the basin may be described as an immense expanse of nearly horizontal strata, upturned on both edges, and modified by erosion, by deposit and by glacial agencies.

The continuity of the plain is disturbed by several subsidiary ranges of mountains or hills; of which by far the most important, especially for our present purpose, is the Ozark range or series of ranges, extending in a direction about south-southwest from the Missouri, near its mouth, to Red River.

Of the immense territory which is drained by the Mississippi, a part belongs, naturally, to the Appalachian system and a part to that of the Rocky Mountains. These two divisions are not very different in size. They are nearly as diverse as can be in their characteristics. One is rocky, the other earthy; one humid, the other dry; one naturally wooded, the other consisting almost wholly of prairie or plain; one geologically old, the other recent. These peculiarities exercise the most remarkable influence on the rainfall, the drainage and the quantity and quality of the contributions to the main stream made by the tributaries passing through the respective portions of its basin.

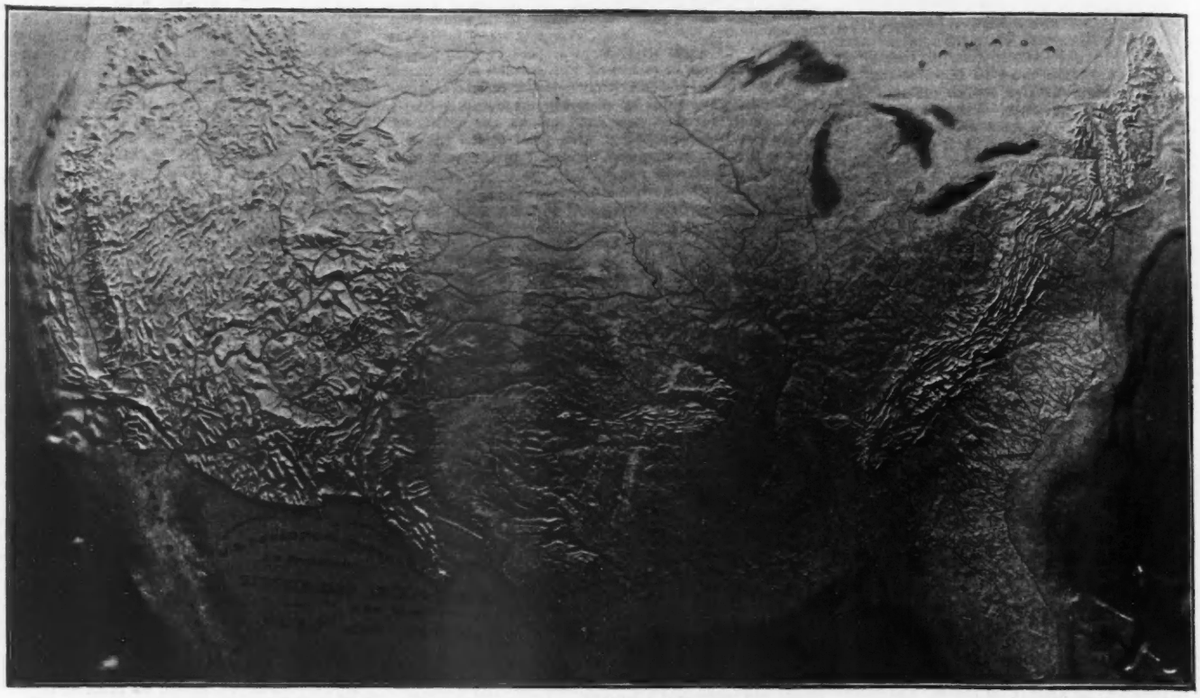
Perhaps the most natural and intelligible division of the Mississippi Basin is into an old and a new part.

The Appalachian Ranges were upheaved at a very early period of geological time, and there has been no material elevation or subsidence of them since. The Rocky Mountains, in their present form, are the product of a very much later age. The Ohio and the Upper Mississippi were old rivers before the Missouri, as we now see it, had an existence. It is considered probable, indeed, that there was, at a very early date, a stream occupying what is now the lower part of the bed of the Missouri, having its sources in the neighborhood of Omaha or Sioux City, and draining the slopes of the Ozark Mountains, for this range is at least of equal antiquity with the Alleghanies. At a later period, the place of the Upper Missouri was partly occupied by a series of great lakes, at first of brackish and afterwards of fresh water. It is considered probable that there was also an Upper Missouri River at this time, which was a tributary to the lake system. These vast bodies of water extended from the Front Range of the Rocky Mountains nearly to the present bed of the Missouri River in the northern portion of its course and to the Ozark hills in the south; and in latitude from Montana and Dakota to Texas. They received the washings of the steep mountain-slopes on the west, which were eroded to an enormous extent during the process of elevation and subsequently. The lakes, therefore, became gradually filled with loess deposits, which sloped away from the western borders, whence they derived their origin, after the well-known manner of such formations. Eventually, through circumstances which are unknown, the lakes found outlets through the ranges which bounded them, and the Missouri and other rivers were formed, nearly as we know them today, but subject to the minor changes which characterized the Glacial, Champlain and Terrace Epochs. The bottoms of these lakes now constitute the greater part of the Plains region, through which flow the Missouri and its tributaries and the Upper Arkansas.

The deposits which were made in the inland seas and lakes just described have never been thoroughly compacted. They consist of sands, clays, marls and soft rocks, which are easily affected by rain, by weather and by currents of swiftly-flowing water, and they have undergone and are still undergoing erosion to a very great extent. Where the plateaus are extensive and remote from the water courses, they are comparatively unaffected by these various influences, and remain unbroken plain; but near the margins of the rivers and creeks and even for several miles back, the descent from the elevated table-lands to the deeply incised valleys of the streams is marked by gigantic phenomena of erosion, resulting in what are commonly called "bad lands;" that is, a country broken to an incredible degree and almost impassable to the traveler; whence its name.

A characteristic superficial feature of a considerable part of the Mississippi Basin is the Drift. This, as is well known, consists of a somewhat heterogeneous mixture of clay, sand, gravel and boulders, left by glaciers, icebergs, glacial lakes, or the floods which proceeded from the melting of the great ice-masses. The manifestations of glacial action proper are almost entirely confined to the older part of the basin, and to only a part of that, namely, to the region north of the Ohio and Missouri rivers, and east of the Missouri. Even of this tract a considerable strip, embracing southern Ohio and Indiana, is exempt, besides the remarkable "driftless area" in Wisconsin. Nearly all the valley of the Upper Mississippi exhibits signs of ice and water action; and a strip along the valley of the Missouri of an average width of, perhaps, 100 miles. The drift deposits often cover the older formations to a great depth, so as to obscure them entirely, except where they are exposed by the erosive action of the streams; and they have a decisive effect upon the drainage of the country, as well as upon the character of the sediment borne by the rivers.

A secondary product of the Drift is a widely diffused deposit called loess, from its analogy to a similar formation bearing that local name on the Rhine. It is a fine, yellowish, marly earth, occurring in masses, often of great thickness and extent, in the Missouri, Mississippi and even the lower part of the Ohio valleys. It covers more than three-fourths of Nebraska and perhaps half



RELIEF MAP OF THE UNITED STATES.

Modeled on a Section of a Globe 16½ ft. in diameter. Horizontal scale, 1 in. = 40 miles. Vertical scale, 1 in. = 8 miles.

By E. E. Howell, Washington, D. C., U. S. Geological Survey.

† This paper was prepared before the present flood was foreseen, and the remarks of the author upon various questions in connection with the subject should be read with this fact in mind.

*Chief Engineer Mississippi Levee District, Greenville, Miss.

of Missouri, as well as large areas of other states, and caps nearly all the bluffs of the Missouri from Pierre down, and of the Upper Mississippi, from Des Moines to the mouth. It forms the bluffs at Memphis, Vicksburg, etc., on the Lower Mississippi.

The boundary between the Appalachian and Rocky Mountain, or Old and New portions of the Mississippi Basin is not easily defined geographically, but may be said, without great error, to lie along the 97th meridian, as far south as Red River and as far north as Yankton, or the mouth of the Niobrara. The Old part embraces all the valley of the Ohio and of the Upper Mississippi, to within a short distance above Cairo, the lower part of the valley of the Missouri proper, from a short distance above Omaha down, and of some of the eastern tributaries of the Missouri, even higher up, and of a part of the Kansas, and the whole Ozark region, including the Saint Francis and White Rivers and the lower part of the Arkansas. The New part comprehends everything else, to the foot of the Rocky Mountains—with the Black Hills standing as an island in it.

The climates of the two divisions are as different as their origin and physical constitution. The upper current of air blowing with approximate constancy from the west to the east, has been almost entirely stripped of its moisture in crossing the Rocky Mountains; and when it reaches the Great Plains it has very little left to impart to the dry and thirsty soil which stands so much in need of it. Were there no modifying influence, therefore, the country to the east of the Rocky Mountains would be as great a desert as that which lies under the lee of the Sierra Nevada. There is a most powerful influence, however, which here comes into play, and that is the Gulf of Mexico.

The effect of this enormous body of warm water is felt to a very great distance. By means of the southerly winds which are so prevalent in the Valley of the Mississippi, the moisture-laden airs of the Gulf are carried far inland, and exercise a controlling effect upon the climate which is within their range. The Great Lakes also exert a certain influence upon the adjacent states, but it is very small in comparison with that of the Gulf, from their limited area and their northerly situation. It is not too much to say that the Gulf of Mexico makes the Mississippi Valley what it is. It even makes the Mississippi River.

The westerly boundary of the Gulf is between the 97th and 98th meridians. West of this line its influence is comparatively small. As the 97th meridian is approximately the dividing line between the old and new parts of the Mississippi Basin, so it is nearly the boundary between the regions of abundant and of scanty rainfall. The limit of the true "arid region" is generally drawn a little further west, about the 100th degree of longitude; shifting, in the northern part of the Valley, one or two degrees still further to the west.

Of the three great tributaries which go to compose the Mississippi, the Missouri has by far the largest drainage-basin, but it lies mostly within the dry or even the arid region. The Upper Mississippi is supplied with a moderate but not a copious rainfall. The valley of the Ohio alone is situated within the zone of heavy precipitation.

The Ohio has a much more southerly origin and course than either of its sister streams. Its extreme northern sources hardly extend beyond the 42d degree of latitude, and its southern tributaries draw part of their supplies of water from springs which lie near the 34th parallel. Its principal affluents drain the warm, wooded and elevated western slope of the Alleghanies. Its valley is spread out directly in the ordinary track of the storms which proceed from the Gulf. Hence, though its basin is considerably less than half that of the Missouri, it contributes more than double the quantity of water to the main river. It drains a territory, according to the Weather Bureau, of about 202,000 square miles. Its rainfall is 43.1 inches, and the proportion of rain which goes into the river-channels is estimated at 32%. The Upper Mississippi with the smallest basin of all, yet has a larger average discharge than the great western tributary. Its valley has a content of 171,500 square miles, a rainfall of 34.7 ins., and a ratio of downfall to drainage of 27%. The Missouri has an immense drainage-area—527,000 square miles—but a scanty supply of rain, 19.6 inches annually. With its highly absorptive soil and with drying winds, a very small proportion of the moisture which descends upon its plains finds its way into the rivers. The ratio is estimated as low as 12%.*

Besides these basins, there is an area of about 14,000 square miles between the mouth of the Missouri and Cairo, which may be considered as belonging either to the Upper Mississippi or to the Missouri. The rainfall in this tract is about 40 inches.

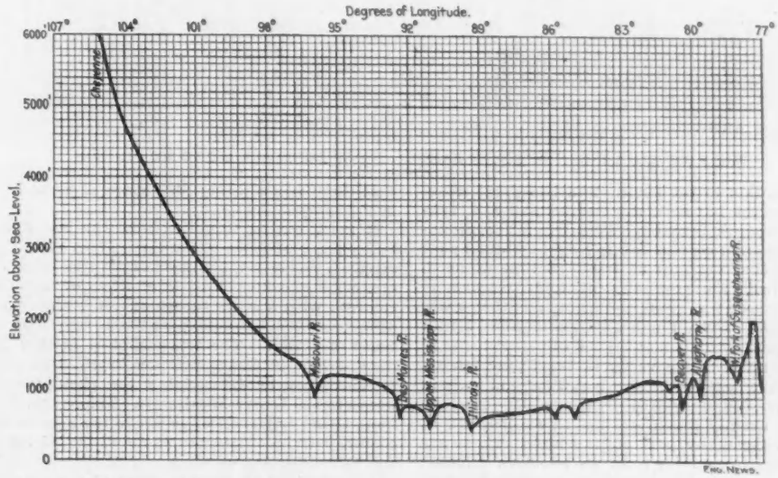
The respective percentages of the total discharge of the main river which are contributed by the Ohio, Upper Mississippi and Missouri are about 31, 18 and 14; the rest being furnished by the small basin just mentioned and by the streams which enter below Cairo.

In view of these facts it might be seen that hydrologically the Missouri was the least important of the great tributaries. In another respect it is the greatest; that is, in the quantity of solid matter which it brings to the Mississippi. Of this it contributes probably about two-thirds.

The physical and climatic peculiarities which have been enumerated have a decisive influence on the character of the streams which flow through the several basins. The Ohio and its affluents run, for the most part, through hard formations, with an abundance of volume in the season of flood, and with a considerable and equable low-water discharge. They are of such antiquity that they have had time to develop their channels fully. They, therefore, have excavated for themselves deep beds in the surrounding rock, often many hundred feet below the general level of the adjacent country. Their waters are clear, except in time of freshet. The Upper Mississippi flows mostly through a region heavily mantled with either drift or loess, usually the former. The superficial deposits, however, are not generally so thick that the stream has not cut down through them to the underlying rock. The result is that the valleys are commonly of moderate depth and width, the river-beds rocky, the hillsides of softer material, clay, sand or gravel. The rain is sufficiently abundant to sustain a forest-growth. The river runs nearly north and south, its sources lying between latitudes 47° and 48°. Consequently it is frozen at its headquarters very early, and remains frozen, sometimes, until late in the spring. The upper part of its basin is distinguished by the great number of lakes and swamps which are found dotting its surface, which exercise a considerable modifying effect upon its regimen.

The tributaries of the Missouri may be divided into two strongly marked classes. The considerable streams which enter it from the east flow through valleys, the underlying rock of which, under the superficial mantle of drift or loess, belongs to the older formations. They, therefore, resemble the tributaries of the Upper Mississippi. Instead of drift, however, the loess predominates; underlain, indeed, by drift, which is usually exposed by the erosion of the stream, or even is itself cut through to the subjacent rock. The rivers, at their sources, are generally merely prairie creeks, which, as they gather strength by uniting with others, excavate for themselves deep valleys, with earthy or muddy slopes and wide bottoms.

The larger western tributaries of the Missouri flow through sandy plains of steep slope, destitute of timber, except sometimes a thin growth along the margins of the streams. As a consequence of the rapid fall (in the case of the Platte, in the lower part of its course, more than 6 feet to the mile) and of the unstable nature of the bed, the streams assume an extremely wide and shallow cross-section. They could not do otherwise. If the channel were deep, the velocity would become uncontrollable, extensive erosion would ensue and the loose banks would fall in. A continuation of this process would give us the very conformation which we now behold as characteristic of the Platte, and of the sandy portions of the Niobrara, Republican, Smoky Hill, Arkansas, Canadian and Red rivers. Another peculiarity of these streams is the scanty volume of the low-water flow. During the intense heat of summer and with the slight rainfall which characterizes the arid region through which these rivers flow, the waters often disappear altogether in the sands, and are not seen again, perhaps, for hundreds of miles. Even when the Platte is at a fair stage, it has been found that the discharge is considerably greater at North Platte, 304 miles above the mouth, than at the latter locality, though several large tributaries intervene between the two points, among them the Loup and the Elkhorn rivers.

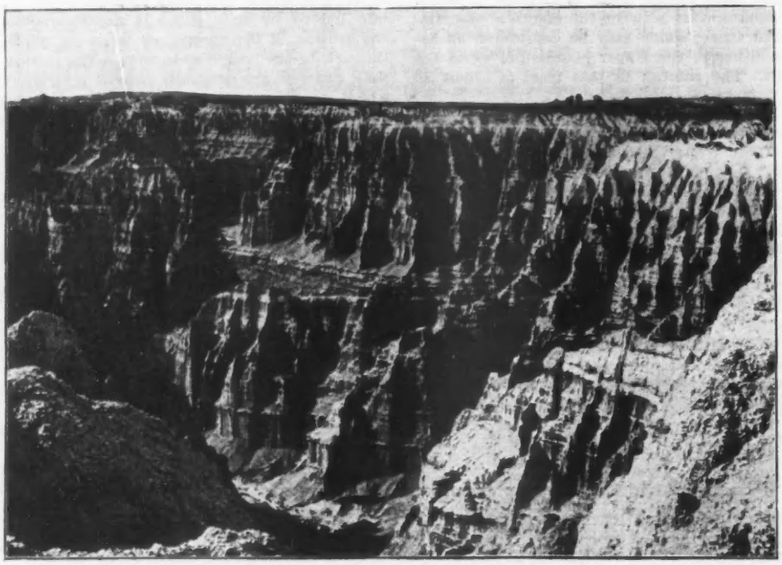


SECTION OF THE MISSISSIPPI BASIN ALONG THE 41st PARALLEL OF LATITUDE.

From the southerly situation of the Ohio, it is the first stream to feel the influence of the Gulf. While the tributaries of the Upper Mississippi and of the Missouri are still locked in ice, the warm winds from the south, while it is yet winter, bring up clouds heavily laden with moisture into the Lower Mississippi Valley, whence they pass, with a slow motion of translation (20 or 25 miles an hour) up the Ohio Valley, where the low wooded ranges of the Appalachians intercept them and strip them of most of their load of water. The months of heaviest rain in the Ohio Valley are January, February and March. If there is any snow on the ground, it is swept away by these rains and added to the volume which they deliver to the watercourses. Therefore, the great floods of the Ohio are usually early, coming occasionally in January, most commonly in February, seldom after March. There are not unfrequently, however, sharp freshets at later

*The areas of the different basins have been taken from the publications of the Weather Bureau, checked by the estimates of Mr. Henry Gannett, in Bulletin No. 47, Eleventh Census. The rainfall and run-off are adopted from Mr. Greenleaf's excellent paper on the Hydrology of the Mississippi, in the American Journal of Science, for July, 1896.

or earlier periods, which, while hardly to be called floods, yet are sufficient to co-operate powerfully with rises from the other tributaries. There is a record of a great freshet in August (in 1875) which reached the proportions of a flood, and did great damage to alluvial lands, sweeping away crops already harvested and others which were



WHERE THE MISSISSIPPI GETS SOME OF ITS MUD.
THE "BIG BAD LANDS" OF SOUTH DAKOTA, SHEEP MOUNTAIN, 600 TO 800 FT. HIGH.

still standing in the fields. The two great tributaries on the left side, the Cumberland and Tennessee, from their extreme southerly range, mountain origin and copious rainfall (50 to 60 ins.) pour out immense volumes of water in time of flood, which, from the proximity of their mouths to Cairo, exercise a great influence on the lower river. They never reach any considerable height after April.

The rainfall in the valley of the Upper Mississippi is the heaviest in May and June and least in December, January and February. Indeed, the river is usually frozen during these months, at least in the upper part of its course. There are sometimes brisk rises from its southern tributaries (such as the Illinois) much earlier in the season, but seldom amount to much before April.

The Missouri Valley is divided by the Weather Bureau into three parts; the Northern slope, the Missouri Valley proper and the Middle Slope, which last takes in also a part of the Arkansas Valley. The "Missouri Valley" division extends no further west that about the 100th meridian. In the Northern Slope, out of a total annual rainfall of about 15.5 ins., only 2.5 ins. fall from December to March inclusive. In the Missouri Valley, out of about 31 ins., only 4.75 ins. fall during the same four months. In the Middle Slope, of a total of 21 ins., 3.25 fall in the same interval. In each of the months of May and June, there falls, on an average, in these three districts, as much rain as during the four months just specified. Consequently the principal floods of the Missouri take place in May and June. The same causes which operate here to produce the rain serve also to melt the snow. With the southern tributaries of the Missouri and of the Mississippi the effects of the snow are considerable. The Platte is said to derive some increments from this source. It is upon the streams which drain the Northern Slope, however, that the melting snows exert the most powerful influence. Rising directly upon the mountain-sides, and having but a short distance to traverse, and that mostly through hard of clayey formations, these rivers are immediately and strongly affected by the liquefying of the snow-caps which crown the northern peaks, though, as may be seen, the rain, which is now in its greatest abundance, is an agent of prime importance in producing the floods.

There are sometimes early spring rises in the upper Missouri from the melting of snow alone, and there are often floods in the lower part of the valley from rains. A considerable part of the immense tract called the Missouri Valley lies, as has been seen, within the belt of moderate rainfall—31 ins. Several important lower tributaries drain the slopes of Ozark Mountains, a region of heavy precipitation, and it has occasionally happened that there was a pretty high stage at Saint Louis in February or March.

It must not be forgotten that the Mississippi, below the confluence of the three great component streams, receives the waters of several large rivers, some of which head in districts of abundant rainfall, with a large percentage of drainage, and consequently contributing, at times, enormous volumes of water. The topographical feature just mentioned—the Ozark plateau—bears a very important part in determining the phenomena of floods in the Lower Mississippi. This elevated region, rising 1,000 feet or so above the surrounding plains, may be considered as an outlier of the Alleghanies. It is a continuation of the carboniferous formations so characteristic of the Cumberland Mountains, uptilted in parallel folds above the nearly horizontal adjacent strata. It lies near the track of the storms from the Gulf, and acts on a small scale as the Alleghanies do further east, attracting to itself a great deal of moisture from the clouds that pass over it. It gives rise to or contributes to half a dozen considerable streams; on the northern and western slopes to the Osage, Gasconade and Meramec, tributary to the Missouri; on the north and east to the Saint Francis and White Rivers, tributary to the Lower Mississippi; on the southern and western slopes to the Illinois (of Arkansas), Grand (or Neosho) and Verdigris Rivers, emptying into the Arkansas, while south of the latter stream, the southern continuation of the plateau, now degenerated into a broken and complicated series or ridges, folds and peaks, called by Dr. Branner the Ouachita Mountains, gives origin to the Poteau and smaller streams and reinforces very largely the supplies of the Canadian and Red Rivers. The annual rainfall at Fort Smith is about 44 ins.; at Little Rock about 54; at Springfield, Missouri, about 47.

The storms which break upon these mountains or high hills are sometimes of great violence. In May, 1892, the rainfall upon the entire Ozark plateau was about 12 ins., of which approximately 6 ins. fell within 4 days. In December, 1895, a precipitation of 3 or 4 ins. in 24 hours caused a rise of 20 ft. in the Arkansas, 22 ft. in the Missouri and 27 ft. in White River. In February, 1882, a rise of 16 ft. in the Arkansas and 18 ft. in the Missouri occurred, at a very critical time, from a similar cause. The fact that these floods discharge almost or quite directly into the great alluvial valley, protected from overflow artificially by a levee system, give them a grave significance.

That part of the floods of the Arkansas which originates in or near the Rocky Mountains has comparatively little effect upon the Mississippi. It is found that even the heaviest freshets in Colorado do not cause the Arkansas to overflow its banks in Kansas, low as they are, the range between high and low water at Wichita being only about 7.5 feet. As one observer expresses it, "The surplus water spreads out laterally and is stored subterraneously in the adjacent porous subsoil." In this respect, as in others, it strongly resembles the Platte. Its tributaries, the Cimarron and the Canadian, follow the same rule, though they do not head high enough to receive any water from melting snow. The former is said to be generally dry, except in time of freshet. The main supply of water, so far as the Mississippi is concerned, from the streams of the Arkansas Basin, is derived from the slopes of the Ozark hills and their continuation, the Ouachita ranges. Their floods, therefore, are exactly contemporaneous with those of the Saint Francis and White Rivers, and the lower tributaries of the Missouri.

The discharge of the Saint Francis, White and Arkansas rivers combined is very little less than that of the Missouri. They contribute about 13% of the total discharge of the main river.

The Yazoo sometimes pours out a considerable volume of water, but, as it empties rather low down, it is only of local importance. The same remark holds good, to a greater extent, of Red River. A part of the flood-discharge of the latter stream passes out through the Archafalaya.

The Ohio, Upper Mississippi and White Rivers are not silt-bearing streams. They flow, for the most part, through hard formations, in stable beds and with a gentle current. Like all rivers, they are turbid in times of freshets, from the detritus which the rains bring down from the hillsides, but as soon as the effects of the storm have passed their waters resume their wonted transparency. The Saint Francis, in general, may be classed with them. The Missouri, Arkansas and Red rivers are generally more or less muddy, flowing, as they do, in the lower parts of their course, through soft and friable beds, partly, at least, composed of their own deposits, and with a velocity sufficient to erode the bottom or banks at all stages, except the

View on Sheep Mountain near the Summit, Showing Strata of the Marl Formation.

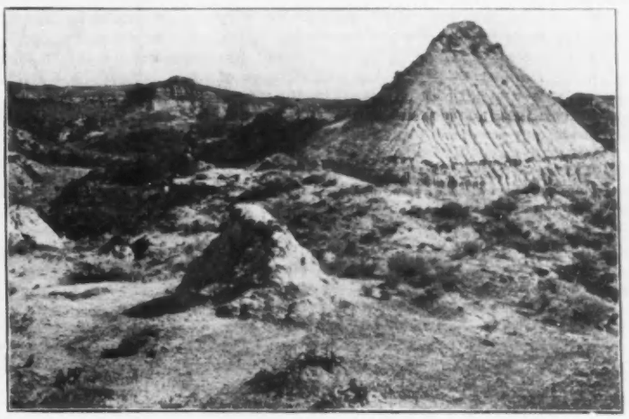
lowest. It is said that even the Missouri is clear in winter, after long rainless periods. Dr. Branner declares that the water of the Arkansas is never entirely transparent, but it is certainly sufficiently near it sometimes to be called clear. The Yazoo, too, is generally a muddy stream.

The quality of the sediment which these rivers bring to the Mississippi is very various. The Missouri is the great purveyor of silt. In the year 1879 Colonel Suter found the mean proportion of

water to sediment, at Saint Charles, near the mouth of the Missouri, 265 to 1. At Fulton, 175 miles below Cairo, in the same year, the proportion was 1,061 to 1. The discharge of the Missouri was about 2,335 to 16,763, or about 14%. The sediment carried by the Missouri was about 64% of that measured at Fulton for the whole united river.

The streams flowing through the bad lands contribute their quota of marly earth, the Platte and Kansas their sands, the Iowa streams their load of loess, added to by the washings of the banks of the Missouri itself. The material thus carried in suspension to the Mississippi is usually very light and finely divided, the heavier and grosser particles being dropped before the main river alone; to the latter the Upper Mississippi, the Missouri and usually the Saint Francis, White and Arkansas. So far as is known, all these streams have never been in extreme flood at the same time. Such an ominous conjunction would produce a discharge of more than 3,000,000 cu. ft. per second, which would be almost twice as great as has ever been observed. But it has often happened that a great flood from the Ohio has met at Cairo a moderate freshet from the western streams, or that a May or June rise from the Upper Mississippi and Missouri has encountered the crest of a late freshet in the Ohio. In either of these cases great floods may and do occur in the lower river by the powerful and decisive aid of the Ozark streams. In fact, it is quite possible for a very great flood in either the eastern or western system, combined with merely an average stage in the other, to produce a very high water below the mouth of the Arkansas. The usual order of floods from the several tributaries is as follows: The Ohio, Cumberland and Tennessee all together; then the Upper Mississippi with the Lower Missouri; then the Upper Missouri. The other western rivers may accompany either or both of the two latter movements.

TYPICAL BAD LANDS FORMATION ON HAT CREEK OR LITTLE BAD LANDS, AT ADELIA, SIOUX CO., NEBRASKA.



VIEW IN THE BAD LANDS OF NORTH DAKOTA.

is reached. The silt is capable of being transported for very long distances, as will appear from the fact that the quantity of matter suspended in the water at New Orleans is much greater during floods from the Missouri than at other times. The sediment from the Arkansas is mostly derived, directly or indirectly, from the Cimarron and Canadian rivers, particularly the latter. This wild stream looks like a miniature Missouri. During and after its canon-like passage through the plateau of the "Staked Plain"* it flows for several hundred miles through gypsum-bearing strata of red clay and sand of Permian and Triassic age, from which it acquires a color that has been aptly compared to that of arterial blood. The banks and bed of the river, even below the "red beds," are composed of the washings of these formations, so that every rain brings large accessions of sediment of the same characteristic hue. The tint is so deep and the material is so intimately mixed with the water that the latter will actually stain the fingers if they are dipped into it. The Canadian gives character to the Arkansas, as the Missouri does to the Mississippi. The red tint is even imparted to the bottom lands of the lower river. During a "red rise" of the Arkansas, in October, 1891, Dr. Branner found that the quantity of sediment carried in suspension at Little Rock, 450 miles or so below the mouth of the Canadian, was 715 grains to the gallon, or about 1-82 by weight. There were also 46 grains carried in solution.* The characteristic color is not lost even by dilution with the waters of the Mississippi; so that pilots and river men pursuing their occupation at Vicksburg or below can tell by a glance at the face of the stream whether the Arkansas is in flood.

For reasons which will be more fully explained in the sequel, the Ohio and its tributaries constitute a system by themselves, and do not generally act in concert with the others, except occasionally with their lower reaches. In fact, the rivers which contribute to the Mississippi may be divided into the eastern and the western systems. To the former belong the Ohio and its affluents

*It is from this circumstance that the river derives its name—Canada being the Spanish for valley.

*In the Missouri, at Saint Charles, a ratio so great as 1-37 has been observed.

It is often affirmed that the principal cause of floods is the melting of the winter's ice and snow. This opinion seems to have a strong hold on the popular mind, and is entertained even by many intelligent people. It is no doubt founded on the imposing and often-observed phenomena of mountain streams. As applied to rivers, the greater part of whose course lies in the lowlands, it may without question be pronounced erroneous. In the case of the Ohio it is well known that some of the greatest floods ever recorded have occurred when there was little snow on the ground. On the other hand, some of the heaviest snowfalls have disappeared by gradual thawing, without rain, and made but a trifling and evanescent impression on the rivers. The most potent agent in producing floods has been excessive rainfall. In making this assertion, it is not intended to exclude the action of snow where it exists. On the contrary, the latter co-operates powerfully with the rain. A deep snow, passing off with a warm and heavy rain, of course greatly augments the effect of the latter, and that, too, at a very critical time. It is true that a foot of snow is only equal to an inch of rain, but when the rain is considerable, every fraction of an inch increases its effective volume for drainage more than proportionately. For instance, in a dry season, an inch of rain will not much more than be absorbed by the ground, especially if it fall slowly, but if two inches fall, the additional inch will nearly all turn to drainage, and of three inches two will be turned into the rivers. Thus a three-inch rain will be doubly as effective as one of two inches, and infinitely more powerful than one of a single inch. Especially will this remark hold good if the downfall be violent and concentrated in a short time. It is obvious that snow acts almost instantaneously to increase the volume of "run-off."

The heaviest, most sudden, most violent, most extensive and most dangerous rains that occur in the Mississippi Valley are those accompanying the cyclonic storms which sweep across the country from west to east in the winter, spring and summer months. These storms pursue several different tracks. They may originate either in the northwest or in the southwest, and may travel either due east, along the Lake region or along the Gulf Coast, or they may move diagonally up the Central Valley in a northeasterly direction. It is said that the lower Lake country and the Saint Lawrence Valley form the great highway for 80% to 85% of all the storms of the United States.

The Coast Range and the Cascade Mountains are lower and more broken and the area occupied by all the chains much narrower in the northern part of the valley than in the southern. It is maintained by the people of Montana and of North Dakota that the mountains intercept a less proportion of the moisture coming from the warm Japan current in the Pacific than they do in Nebraska or Colorado, and that their country, in consequence, is comparatively well watered. It is said that there is a permanent low area in the North Pacific, and that this contributes many of the storms which appear in the Northwest.* Usually, between the mountains and the Mississippi Valley, the precipitation is mostly confined to the southeast quadrant of the storm area. In the storms of the northwest there is sometimes considerable rain or snow on the west and northwest sides of the low area. Most rain-bearing storms, however, owe their origin to the Gulf of Mexico, and do not attain much intensity till they have passed within its sphere; that is, roughly speaking, till they have arrived east of the 97th meridian. The dangerous quadrant is usually the southeastern. All of these disturbances are of the cyclonic type, characterized by winds blowing spirally out of high areas in the direction of the hands of a clock and into low areas and around them, counter-clockwise.†

The rain-storms which arise in the winter and early spring are mostly of southern origin. At that season the temperature in the north is usually so low and the prevailing barometer so high that the warm winds from the Gulf are not attracted in that direction for any considerable distance. At this time low areas may, and frequently do, originate in the northwest and move down the eastern slope of the Rocky Mountains, but the storms which attend them are generally accompanied by very little rain till they reach Oklahoma or Texas. In the latter region they often incubate, as it were, for a day or two, gathering intensity before proceeding further on their eastward voyage. Indeed the movement even of a far northern low area (for instance, across the lower Lake region), will frequently cause a strong influx of southerly winds along the Gulf Coast, or

*See Professor Hazen's paper on the Climate of the United States, in the Report of the International Meteorological Congress, part iii., p. 585.

†See Hazen, p. 586.

up the Ohio Valley, attended by rain. The inland range of such disturbances is generally limited.

The most formidable of all storms, however, so far as rainfall and floods are concerned, are those which originate in the Gulf itself. They cannot usually be predicted by the observers of the Weather Bureau, because there are no meteorological stations in the Gulf. Their approach is often suspected from an unusual prevalence of southerly winds and an unnatural warmth. The first formal warning that is given is the appearance of low area at Brownsville, or somewhere in southeastern Texas. Often when a low area is passing far to the north, a secondary "low" develops in the southwest. The storm center then moves slowly to the northeastward, up the Ohio Valley, but sometimes nearly east along the Gulf Coast.

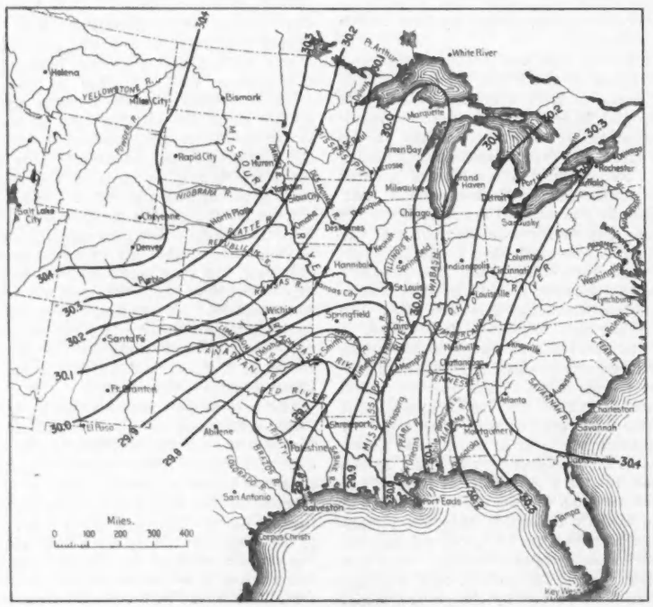
Gulf cyclones are generally marked by very warm, southerly winds, very low barometer, dense, heavy, threatening clouds, with low "scud" flying, much thunder and lightning and deluges of rain, which last is not merely caught by the mountain ranges that intercept and, as it were, strip the clouds, but also falls in profusion on all parts of the lowlands that lie in the track of the storm. The passage of one of these cyclones often occupies two or three days, and a rainfall of three inches is not unusual. A considerable flood has been known to result from two of them, at an interval of about a week apart. The time was from the 26th of March to the 2d of April, 1886. There was little snow on the ground, and the rivers were decidedly low. These storms are supposed to follow somewhat the direction of the prevailing current of the upper air, though modified by local conditions. Consequently their general tendency is easterly. In the Ohio Valley, they seem to be deflected somewhat toward the north, and to move nearly parallel to the ridges of the Alleghanies, skirting the western slopes of the mountains and passing out at the mouth of Saint Lawrence. Here, at all seasons, there is a permanent area of low barometer.

The Ozark region does not usually participate to any great extent in the storms of December or January, though often in those of February. April and May are the months of the highest water at Fort Smith and Little Rock. As a general rule, it may be said that the Ozark plateau does not lie directly in the path of the Gulf storms of the earlier months, but rather of those of the later spring and summer. The rivers which drain the western and northern slopes especially may be classed rather with the western than with the eastern tributaries, though this rule is subject to striking exceptions.

The upper waters of the rivers of the western system are not usually encountered by storms which proceed directly from the Gulf, though their lower tributaries often participate in their effects.

Cyclones of this type, either arising in the Gulf or incubating in its vicinity, on the plains of Texas, have been known to prevail for weeks, one following the other at short intervals—two or three, perhaps, in a month—drenching the whole country through which they passed, as probably in the famous season of 1867, and certainly in the more famous one of 1882. In the latter year, the rainfall in the Ohio Valley for January was 60% more than the normal for the month. In the valleys of the Cumberland and Tennessee it was three times the average. In the Lower Mississippi Valley it was more than double the mean. In February, for the Ohio Valley, the excess was 70%; for Tennessee, 65%; for the Upper Mississippi, 50%. The extreme height of the flood reached at Cairo on the 26th of February. In February, 1884 (flood month), Ohio Valley, 70% excess; Tennessee, 70%. In both 1882 and 1884 there was a good deal of snow on the ground at the end of January—perhaps 3 or 4 ins. In January, 1890, Ohio Valley and Tennessee, 75%

AVERAGE ANNUAL RAINFALL OF THE UNITED STATES.
(Figures show total depth in inches.)



COURSE OF THE CYCLONIC STORM OF JAN. 1-2, 1897.
(Figures show barometer heights).

excess; in February, 60%; in March, 40%. There was excessive rain in the valleys of the Arkansas and White rivers, especially the latter. At Dardanelle, on the southern slope of the Ozarks, on the Arkansas, in the four months from January to April, there fell 39 ins. of rain. At Newport, on the eastern slope of the plateau, on White River, the rainfall, during the same time, was 40 ins. White River was at a high flood stage continuously during this entire interval. In the lower river, the flood was in March and April.

In 1882, of the total discharge which passed Cairo, 69% came from the Ohio; in 1883, about 70%; in 1884, about 85%; in 1890, about 75%. The three great floods first named culminated at Cincinnati from the 14th to the 24th of February; at Cairo from the 22d to the 27th. They attained a greater height, at the latter point, than has ever been known before or since.

As the season advances, the power of the sun begins to be felt in the northern part of the Great Valley. The high area which had dominated the Rocky Mountain region moves out to the Pacific; and its place is taken by a low area.* The winds from the Pacific retain more of their moisture, after passing the several chains of the Mountains, and the winds form the Gulf have a more northerly range. The storms, whether from the Gulf direct or merely modified by its influence, no longer are arrested and confined to southerly latitudes, but diffuse the waters which they bring with them over the Plains and the Central Valley. The track of the storms is no longer up the Ohio Valley. The Cumberland and the Tennessee never come out after April, and the Ohio very rarely.

The flood of 1892, which came mainly from rains in the Central Valley (Upper Mississippi below Dubuque—Missouri below Sioux City—Ozark region) culminated at Cairo on the 28th of April. Before this had time to recede it was caught by another which reached its maximum on the 25th-26th of May. The rainfall for April in the Upper Mississippi Valley was 80%, in excess of the mean; for the Missouri Valley, 80%. In May, Upper Mississippi, 80% excess; Missouri, 60%; in the valleys of the Arkansas, White and Saint Francis, 87%.

*See Professor Hazen's paper already quoted.

There was a great flood at Saint Louis, the highest since 1858, which reached its height on the 19th of May; a very great one at Fort Smith, the highest on record; and at Little Rock the highest since 1833. The Ohio was at less than flood-stage throughout. At the height of the flood at Cairo, the percentage of water which passed Saint Louis was probably about 55; on the second rise, about 74. In 1858 there was about the latter proportion.

Thus, there are two classes of floods which affect the alluvial plain of the Mississippi; the early floods which proceed mostly from the eastern rivers, and the late, which owe their origin principally to the western streams. The former usually reach their height in the lower valley in March, the latter in May or June. Sometimes there occur very high waters of a third class, intermediate between the two, in which a late rise from the Ohio meets an early freshet from the Upper Mississippi and Missouri, accompanied, as usual, with heavy rises from the lower streams. Such floods culminate in April or May. Instances are 1874, 1876, 1893. It is a question which of these is most dreaded by the dwellers in the alluvial region. The March floods are frequently very great in volume, come up very rapidly and take place at a very inconvenient and inclement season. Now, the law of winds, discovered by the eminent Dutch meteorologist, the late Professor Buys Ballot, is this: In the Northern Hemisphere, to an observer standing with his back to the wind, the storm-center or low area will be on the left hand. In the Southern Hemisphere, the low area will be on the right hand. In accordance with this law, which seems to be fully established by experience, if a storm-center be traveling the usual path of the winter or early spring cyclones, that is, from Texas up the Lower Mississippi and Ohio valleys, to the watcher on the levees below Memphis, during the passage of the southeast or rain-bearing quadrant of the storm, the center of the low area will be on the left and the winds from the south. After the transit of the storm-center to the east, or during the "clearing-up," the wind blows from the north. The shift is generally very sudden, and the transition from the warm Gulf-breezes to the freezing blasts from Dakota is rapid and violent. Sometimes the path of the low area is to the south of the observer, or along the Gulf coast. In such a case the wind will at first be from the east or southeast, and will "back-up" to the north, in the reverse of the ordinary direction, as the center passes the meridian of the observer. Such a phenomenon generally produces cold rains, accompanied by sleet or snow. It is not very common.

The winds which accompany the February and March cyclones are frequently very heavy. Especially the northers which prevail after the passage of the storm-center are extremely cold, violent and persistent, and are also accompanied oftentimes previous to the clearing with snow or sleet. On these occasions the tempest sometimes blows with almost undiminished strength for 36 or 48 hours. Should the river be standing very high against the levees, the energy and fortitude of those in charge are taxed to the utmost. The Mississippi, at such times, presents a formidable expanse of water; and at places where the foreshore is narrow, or where it is covered to a considerable depth with the overflow, and where there is no protection from timber-growths, etc., the waves which are generated are of height and strength enough to be very dangerous to a mere earthen embankment. Even a flat slope and a well-matted sod present no effectual defense against a severe storm. The waves are especially high when the wind is blowing up-stream, or in situations where there is no current at all, as in "old river lakes," left by cut-offs.

In older countries, and where the dike-system has reached its full development, as in Holland, Germany and Italy, provision is made against such perils by permanent revetments of stone; and doubtless in the end a similar course will be adopted for the levees of the Mississippi. The latter have not yet arrived, however, at a stage when it would be good economy to build expensive and lasting works of defense. They are still in a state of transition, struggling toward completion; and probably they will have to be enlarged two or three times before they reach ultimate grade and dimensions. Resort then must be had, in emergencies, to temporary measures of protection, such as have already been described in these pages.* It is sometimes difficult to get men to work at all in the face of a cutting and freezing wind, spray and rain; and not unfrequently the emergency comes on during the night. Such work was formerly entrusted to volunteer inspectors, who called upon the neighboring planters and their tenants for assistance. Now it is the practice to employ organized forces; and the latter method is far more satisfactory and economical. To the novice it always seems wonderful that earthen dikes can be held at all against such heavy odds, and yet it is but seldom that they are lost from such a cause.

The engineer, then, would rather undertake to hold his levees in May or June, when the sun is warm, the air genial and mild, the earth dry and the days long. Then his men are cheerful and willing, and, if they are negroes, sing all the day as they work. But the planter dreads a summer flood. Should the levees break and he be overflowed in March, the river will probably subside in time for him to make a crop. But if such a misfortune happen in May or June, it will be too late to calculate on a full return, and he must either lose the season altogether or incur the expense of replanting with a prospect of only half a crop or thereabouts.

The task of holding the levees is greatly facilitated, as the season advances, by the slackening of the violence and severity of the storms. There are frequently high winds in April, but they are generally from the south, and blow themselves out after a while. Still more is this the case during the following months, when the violent gusts seldom last more than half an hour.

There is an evil attending floods, from which levees are no protection. This is seep-water, or leak-water, which filters through the pores of the ground, under the base of the embankment, and invades the roots of the growing corn and cotton, to their great injury and probably destruction. This evil, too, is far more damaging when it comes at an advanced season after the ordinary time of planting.

(To be continued.)

*See Engineering News for January 30, 1896, Vol. xxxv., pp. 66 and following.

SPECIFICATIONS FOR MALLEABLE IRON CASTINGS.

Despite the very wide use of malleable iron castings, and notwithstanding the quite general belief that not a few of the castings sold as malleable iron are but little better than good gray cast iron, very little seems to have been done toward working out any standard practice in specifying the requirements which should be demanded of this material. Indeed, it is certainly not easy, if it is possible even, to find a single set of specifications for malleable cast-iron castings which are worthy of the name. For this reason the following suggestions for standard specifications, abstracted from a paper read before the Western Railway Club, March 16, 1897, by Mr. C. L. Sullivan, of the National Malleable Castings Co., of Chicago, Ill., are of especial interest:

Tensile Requirements.—At the option of the inspector, one, two or three castings of either the same or different patterns shall be selected from each 2,000 lbs. of finished product. From one or all of the castings thus selected test pieces shall be cut and prepared; one from each selected casting. The position in the casting from which the test piece shall be cut is to be determined by the inspector. The size of the test piece shall be, as nearly as possible, such as will give, when the piece is prepared, a uniform clear length of 4 ins. between the grips of the testing machine, and such as will give, as nearly as possible, a cross-section area of ½ sq. in. Tests of one or each of the pieces thus prepared shall show a tensile strength of not less than 40,000 lbs., and not more than 47,000 lbs., per sq. in. The elongation and reduction of area measured after fracture shall be distinctly noticeable as indicating some degree of ductility, and should be at least 1.5% for each. Should the average of three tests show a tensile strength below 43,000 lbs., and coupled with this if ductility is not plainly discernible, the inspector shall have the option of repeating the test.

Transverse Requirements.—Besides the tensile tests, transverse tests shall be made as follows: From the same castings, or others, at the option of the inspector, one, two or three test pieces shall be prepared, giving a length of 12 ins. between centers of supports and having as nearly as possible a cross-section of 1 sq. in. If there should be any difference in the dimensions of the sides, the piece should be set in the machine with the greater dimension vertical.

The supports shall be 12 ins. apart, center to center, and of the usual shape for making transverse tests of gray iron castings. Tests of one or each of the test-pieces thus prepared shall show an ultimate tensile transverse strength of from 3,900 to 4,800 lbs. per sq. in., and deflections from 0.35 to 0.65 in. The average breaking load for any number of tests should be about 4,900 lbs. per sq. in., and the average deflection about 1.5 in.; this for specimens of the sizes recommended and for a metal of the characteristics suitable for car castings.

The fractures in both tensile and transverse tests should be fine grained and uniform; blow holes should be absent; bright edges like the chill in chilled castings should generally show distinctly at the edges; the center should generally appear almost as dark as burnt iron. No great dependence, however, can be put upon an examination of the fracture in determining the quality of malleable castings, further than seeing that castings are of uniform fine grain and free from blow holes, as the fracture will vary in appearance according to the size of section.

Bending and Torsional Tests.—Malleable castings which successfully pass the above requirements in tensional and transverse tests will generally successfully pass bending and torsional tests of equivalent severity. Reasonably thin sections, about 3-16 to 9-16 in. thick, by about 1 to 3 ins. wide, should bend over on themselves around a circle at the bend equal in diameter to twice the thickness of the piece and back again straight. And in torsion a thin piece of uniform dimensions, or nearly so, should twist once around without fracture. It only requires proper mixtures and proper annealing, coupled with care in other particulars, to make malleable castings that will weld on themselves; that will draw out to a knife edge on an anvil under a hammer; that will temper and cut soft iron like a cold chisel. Such castings, however, cannot be had at the prices at which some malleable castings are quoted, and probably such qualities are not required in car castings.

Notes and Instructions to Inspectors.—All tests should be made at the place of manufacture prior to the shipment of the castings. Extra castings from which to cut test pieces or test pieces cast in molds, and the preparation of test pieces shall be made at the expense of the manufacturers. Test pieces cast in molds are to be furnished if required. If manufacturers have no means of making tests, the expense of making tests elsewhere shall be borne equally by manufacturer and purchaser. Purchasers should have a knowledge of the reputation for the quality of work of the several malleable foundries. Planed and turned test pieces should be tested occasionally to determine the penetrative effect of annealing. The effect of suddenly applied loads corresponding to shocks should be determined by some convenient tests. In carload shipments the inspector is to determine whether but three test pieces shall represent the car load. If a car load is made up of such a great variety of patterns as not to be fairly represented by three test pieces, and if there is any doubt in the mind of the inspector as to the uniformity of product in the car load lot, he shall test enough pieces to represent fairly the whole lot. It is almost impossible, from the limited amount of information on the subject of malleable castings, to determine upon requirements in bending and torsional tests. It is quite certain that one set of requirements will not do for general car and locomotive machine and agricultural castings. As we are dealing with railroad castings, our requirements are made to fit them only. If patterns are furnished by manufacturers, inspectors shall insist that all abrupt changes in forms shall be relieved by fillets. In case of duplicate patterns, castings from same shall compare closely in weight. All castings shall compare closely with guaranteed weights when in competition with gray iron castings. Besides making tensile and other tests, inspectors shall closely inspect all castings, rejecting all that show unmistakable defects, such as shrinkage cracks, large ridges at partings, evidence of blow holes, castings badly warped, cracked or broken castings, castings not properly cleaned, castings that are incorrect in important dimensions due to errors in patterns, castings requiring cleaning, pickling, or machining not previously agreed upon.

THE DESIGN OF FACTORY CHIMNEYS is discussed by M. Bassine in the "Zeitschrift des Vereins Deutscher Ingenieur," for March 6. He considers a chimney as a vertical beam, fixed at the base, and determines the limiting conditions of pressure and tension in the different horizontal sections. He recommends an exterior profile, with a batter ranging from 33.3 on 1 to 25 on 1 and divides the vertical height into sections of from 16 to 20 ft. each, with the thickness of the wall constant for each section and decreasing by 1.5 to 2.5 ins. in each ascending section. He prefers an octagonal base with a height equal to one-fifth of the height of the chimney. The foundation should be a truncated pyramid with a square base and sides inclined at least 45°, and the length of the sides of the foundation should vary between one-seventh and one-eighth of the height of the chimney proper.

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AND
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ADVERTISING RATES: 20 cents per line agate measure. Want notices, special rates, see page 22. Rates for standing advertisements sent on request. Changes to standing advertisements must be in hand on Monday afternoon; new advertisements, Tuesday afternoon; transient advertisements by Wednesday noon.

During the past week the publication offices of this journal have been removed from the seventh floor of the Tribune Building to the nineteenth floor of the new St. Paul Building. As some of our old subscribers may recall, the offices of Engineering News have been in the Tribune Building ever since their removal from Chicago 20 years ago. At that time, the Tribune Building, with its ten stories, was one of the wonders of New York city. It was the first of the hundreds of modern fireproof, many-storied office buildings, and its tall spire was as conspicuous a landmark in that part of the city as was Trinity Church spire on Lower Broadway. Some of our long-time readers may remember, indeed, when a picture of the Tribune Building was printed on the envelopes of Engineering News, and there was reason in placing it there, not only to familiarize readers in distant parts of the country with the habitation of Engineering News, but because the managers of this journal were proud of its location in a structure whose name was familiar the country over.

But the score of years during which Engineering News has had its home in the Tribune Building has seen vast changes. That structure's once tall tower is now dwarfed and lost to view among the lofty buildings that overlook it on each side. The convenience and comforts of the modern office building, which were so remarkable a score of years ago, are now commonplace necessities. Engineering News, as first issued from the Tribune Building was a small affair. A single cramped office sufficed to conduct all its business and its editorial work as well. In a few years larger quarters were secured on the sixth floor, and nine years ago what seemed at that time a commodious suite of offices was taken on the seventh floor. But while the growth of the journal has steadily continued, circumstances prevented a corresponding expansion in the space occupied by its offices. The need was also felt of a location somewhat nearer to the engineering and financial quarter of the business district, which centers on Lower Broadway.

To this end the Engineering News Publishing Co. a short time ago leased for a term of years the 19th floor, with the exception of the wing, in the St. Paul Building, a new 25-story building, which has been built by Mr. H. O. Havemeyer on the site of the old Herald Building, at the intersection of Broadway, Ann St. and Park Row. The building and its structural details were illustrated and described in our issue of May 7, 1896.

The building takes its name from St. Paul's Church, which stands on the opposite side of Broadway, surrounded by an ancient graveyard, that makes a welcome oasis in the midst of the lofty structures around it. Some of the older of our readers may doubtless remember that the St. Paul Building stands on the site of P. T. Barnum's once famous museum, which was destroyed by fire in the 50's. Diagonally across Broadway is the old Astor House, as well-known a landmark in the downtown district as Trinity itself. Directly north and occupying the entire space between Broadway, Park Row and the City Hall Park is the New York Post Office.

For the benefit of the stranger to New York city, who may have occasion to find our offices, we may add that the Broadway cable cars pass the door. The Third Ave., Fourth Ave., Eighth Ave. and a number of east side horse car lines have their downtown terminus just in front of the building. It is within short walking distance of the City Hall, Fulton St., Park Place, Cortlandt and Barclay St. stations of the Manhattan Elevated Ry., and also of the downtown ferries on the North River. It will be convenient, also, to remember that the nineteenth floor, over 200 ft. above the street level, where our offices are located, is reached by express elevators, which make no stops below the 16th floor.

We risk little in saying that Engineering News has now the highest offices of any engineering journal in the world, and it will be our constant endeavor to make its position in the scale of excellence harmonize with its physical location.

We presume not a few of our readers in these past weeks, when public attention has been so generally turned toward the Mississippi River floods, have recalled the valuable paper on the levees of the Mississippi by Mr. Wm. Starling, which we published about a year ago, and have turned back their files to read it. In the present issue we have the pleasure of presenting to our readers the first installment of another paper from Mr. Starling, on the Floods of the Mississippi River.

In publishing Mr. Starling's paper last year we remarked the very great literary merit of his production; and this is still more apparent in the present paper. He has written a technical paper which is as entertaining as a novel; and he has succeeded in doing it, first, because his subject is an interesting one; second, because he is himself deeply interested in it, and, third, because he knows how to use language to convey his interest to others. We believe it is well worth while emphasizing the fact that these three elements are a necessity to the production of any first-class piece of engineering literature, whether it be a student's thesis, a paper for an engineering society or an engineering journal, or even a specification for a piece of engineering work. With any of these three lacking the production is bound to be second rate; but we are inclined to think that the most essential one of the three is the interest that the author feels in his subject.

The man who is an enthusiast upon even a dry subject can often awaken a considerable degree of interest in others. But if a man has only a languid interest in a subject, how can he expect to excite more in those for whom he is writing?

We commend Mr. Starling's paper again as a model to young engineers who are striving to improve their literary style, but we remind them at the same time that his deep interest in the topic on which he writes and the years of study he has given to it are an important element in his success in holding the attention of the reader.

Concerning the subject which Mr. Starling's paper discusses, we may have more to say editorially next week, but it is due to the author to call attention to the fact that his paper was written several months ago, and was, in fact, accepted for publication before the present great flood was ever foreseen. The records of this present flood, when completed and studied, are expected to shed much light upon various controverted questions in connection with the control of the great river.

The Westinghouse Air Brake Co., on April 16, passed the half-million mark in its shipment of air brake equipments for freight cars. Its total sales of freight brakes on that date amounted to 503,519 sets. This enormous production of an apparatus, which at this time ten years ago was still in the experimental stage, is a remarkable record, and one on which the able managers of the Westinghouse Brake Co. are to be congratulated. Still more deserving of congratulation, because the interests they have at stake are greater, are the railway freight trainmen of the country. Half a million air-braked freight cars in service means that a very considerable proportion of the freight trains now in service are partially or wholly controlled by the air brake, and the number will rapidly increase from now on. The difference from a humanitarian point of view between applying the brakes by the turn of a handle in the locomotive cab and sending a train crew along a heavy train to set the hand brakes, is one which can be fully appreciated, doubtless, only by a man who has known what it is to run along the swaying roofs of a string of freight cars on a black night, or when the running boards are coated with ice, or when the wind is blowing a gale. It is this part of the railway trainman's work that has cost most lives, although the link and pin coupler has made the most cripples.

As for the benefit which the railway corporations have reaped and are still to reap from the freight air brake, we do not know whether to congratulate them upon it or not, since in the kindness of their souls they have given to the public all this benefit, in the shape of better service at lower rates. Certain it is, that the freight air brake has made possible a remarkable increase in freight train speeds, and the handling of larger and heavier trains. Under old ideas of train resistance "fast freights" used to be considered an expensive luxury; but the saving in trainmen's wages far overbalances any additional cost for fuel when trains are run at high speed. The public, then, if not the railways, is to be congratulated that, thanks to the genius and enterprise of Mr. Geo. Westinghouse and his associates, its goods are carried considerably more cheaply and promptly than they could be were the hand brake in as universal use on freight trains as it was a decade ago.

The production of pig iron on April 1, according to the "Iron Age," was practically the same as on March 1, the figures being for April 1, 173,279, and for March 1, 169,986 gross tons per week.

Prices of pig iron are now lower than were ever before known in the history of the trade. Bessemer pig is quoted as low as $9.60 in Pittsburg, and Southern gray forge at Birmingham, Ala., as low as $5.75. Steel billets are $14.50 and steel rails $19 at Pittsburg. It would seem as if these low prices should stimulate buying, but the market is still reported as exceedingly dull. The "Iron Age's" London cablegram of April 14 shows that English prices of iron and steel are now higher than American. American pig, grade not stated, is quoted at 45s. 6d. ($11.07), delivered at Manchester, which is a trifle higher than is quoted for No. 1 Southern foundry pig at New York. Steel rails are quoted in England at 90s. ($21.90); steel billets, 82s. 6d. ($20.08), and tin-plate bars 80s. ($19.47) for Siemens, "under the influence of increased arrivals of American." The iron trade in England is fairly active, with production going on at the highest rate ever reached, in marked contrast to the condition of the American trade. So long as the present trade conditions continue there is likely to be an increased demand in Europe for American iron and steel.

A CHANGE IN THE REQUIREMENTS FOR ADMISSION TO THE INSTITUTION OF CIVIL ENGINEERS.

The Institution of Civil Engineers is at once the largest engineering society in the world and the society in which the requirements for admission to full membership are, at least nominally, the most severe. In the recent presidential address by Mr. J. Wolfe Barry, the need was set forth of some radical changes in the rules covering the admission of new members. These recommendations

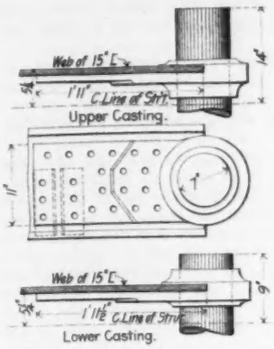


Fig. 7e.
Cast Steel Bearings for Swinging Struts.

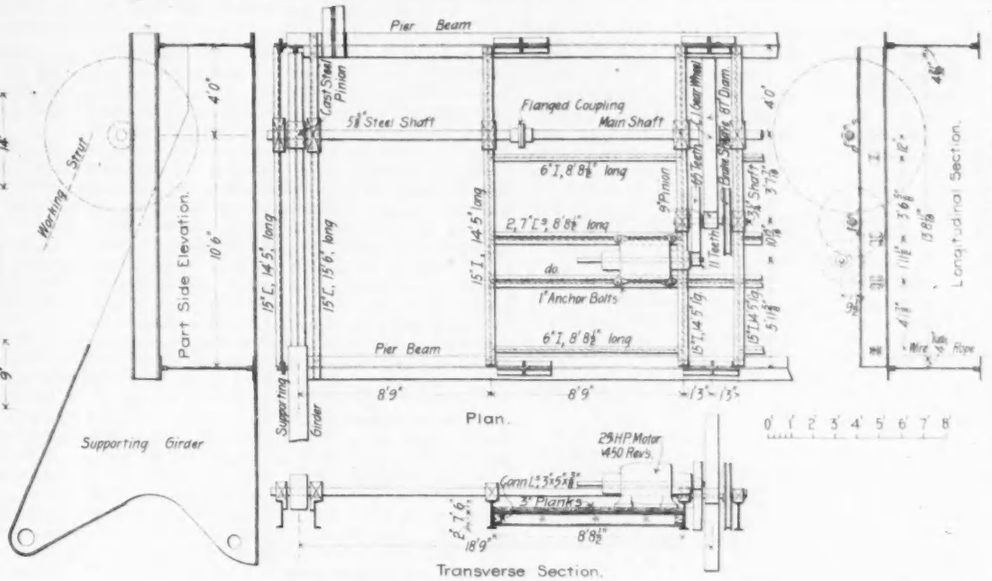


FIG. 6. GENERAL PLAN OF MACHINERY FOR OPENING AND CLOSING DRAW.

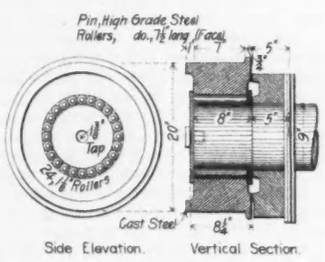


Fig. 7d.
Detail of Rollers.

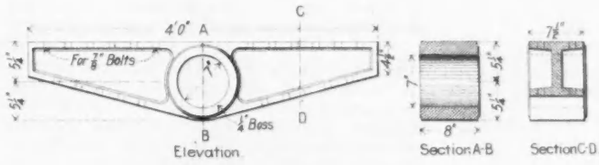


Fig. 7a.
Swinging Strut Connection to Main Girders.

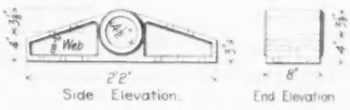


Fig 7c. Operating Strut Connection to Main Girders.

Scale for Fig 7

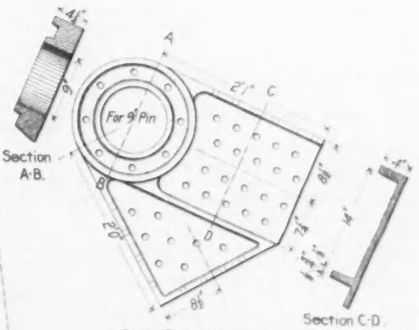


Fig. 7b.
Cast Steel Bearings for Roller Pins.

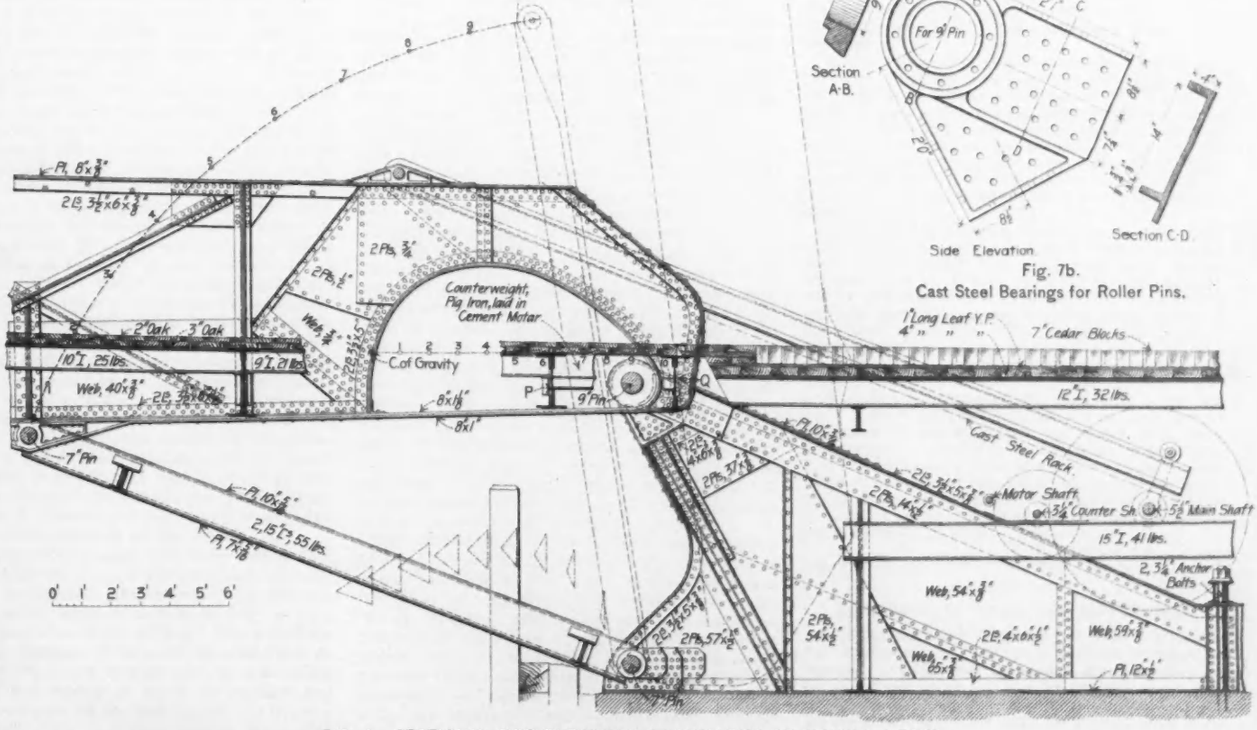


FIG. 8. SECTIONAL SIDE ELEVATION AT REAR END OF MOVING GIRDER.

HURON ST. LIFT BRIDGE, MILWAUKEE, WIS.

M. G. Schinke, Assistant City Engineer, Designing Engineer. **Milwaukee Bridge & Iron Works, Contractors.**

CHAS. HART & SONS, LITH., 90 VESEY ST., N. Y.

were taken up and formulated by the Council of the Institution as definite amendments to the by-laws; and these amendments were approved by the Institution itself at the general meeting just held.

According to these amended rules, while as an occasional thing candidates may still be admitted directly to full membership, the intention is that full membership shall as a rule be attained by promotion from the lower grades of membership in the Institution. The age limit for election to full membership is raised from 25 years to 30 years, and in the description of the requirements for associate membership in the rules the words "the usual routine of pupilage" are omitted. This is, of course, in recognition of the fact that graduates of engineering schools are rising to eminence and distinction in the profession who have never gone through the old routine of being "articled" to a practising engineer. The most notable feature in the new requirements, however, is that which proposes that the candidate for associate membership shall pass a prescribed examination as a test of his professional ability and fitness for membership. The intention is, apparently, that this shall hereafter be the ordinary routine for admission to membership. Of course, the examination is only one of the requirements. In addition the candidate must be actually engaged at the time in the design or construction of such works as are comprised within the profession of a civil engineer, as defined by the charter. But besides the admission by examination, two other doors are left open for the admission of members. A candidate may, for one thing, satisfy the Council that he has had a training in engineering, has been engaged in the practice of his profession for at least five years, and in addition shall furnish a satisfactory thesis or paper on some professional subject. Finally, a candidate may be elected to membership without either thesis or examination, if he affords to the Council satisfactory proofs as to his professional abilities and his fitness for membership.

Our London contemporary, "Engineering," sees danger in these constitutional changes, and while expressing every confidence in the wisdom and good intentions of the Council of the Institution, it fears that a door has been opened for the operations of a party, already in existence within the Institution, which will seek to make a "close" profession of engineering, similar to the professions of law and medicine. The great bulk of present engineering work, says that journal, is now performed by men most worthy and competent as engineers, but to whom has been denied the gift of literary expression; and no engineer need be told that judgment, experience and mechanical ingenuity play a more important part than mere abstract scientific knowledge in the execution of engineering works. If college-acquired knowledge, as exemplified in answers to examination papers and in well written theses on professional subjects, should hereafter be made the sole means of admission, a most valuable class of recruits would be shut out from the Institution, and the usefulness of that body in the future material progress of the country would be to that extent curtailed. The option is left with the Council, by the changes which have been made, to select any one of the three paths of entry into the Institution and make it practically the only one available; for the power of the Council is so supreme that it would be possible, some time in the future, for a very small body of men to decide upon any one of these paths to the practical exclusion of the others.

Our contemporary might well have added that the reason why the Council has such supreme control of the Institution's affairs is the fact that the great bulk of the members have absolutely no voice in the management of the society. The American letter-ballot system, which enables a member in any part of the world to take part in controlling the affairs of a society to which he belongs, has never been adopted by the Institution, and the few members who reside in or near London are in sole control of the affairs of an association of 6,000 members, scattered in all quarters of the globe. If the danger which "Engineering" points out is a real one, the best way to meet it will be to agitate for the enfranchisement of the non-resident members of the Institution.

We agree with "Engineering" that much of the past prosperity of the Institution of Civil Engineers is due to the admission of fresh blood from many worthy sources, and to the fact that the experience and ability to efficiently carry out engineering work have had more influence in the selection of candidates for election to membership than the possession of scientific education and the ability to write professional papers. But we differ somewhat with that journal as to the dangers which may result in the future from requiring examinations and the submission of these as a preliminary to admission to Associate Membership in the Institution. Engineering is the youngest of the learned professions; and a beginning had to be made in it with men who were self-taught, simply because no opportunities for engineering education existed up to a few decades ago. But at the present time there is an abundance of schools which are as well equipped for training young engineers as the older professional schools are for launching young doctors and lawyers upon their career. If public policy demands that lawyers and doctors shall have a license from some duly authorized body before commencing the practice of their professions, why should not the same demand be made upon young engineers. The interests placed in the hands of the latter, and depending upon their judgment, training and personal ability, are quite as important to the public. The doctor may bury his mistakes, and if the lawyer loses his case it means that one man wins and the other loses; but the mistakes of an incompetent engineer may mean the loss of a large amount of property, as truly wiped out as if fire had swept it away.

Of course it must be freely admitted that one great difficulty with any plan for making engineering a "close" profession would be the selection of a body which should be at once competent to pass upon the fitness of candidates to practice and able to command public confidence in its competency and integrity. Certainly no elected or appointed public official or board of officials could be safely entrusted with this work. That might lead to the spectacle of a Republican board denying to Democratic applicants the right to practice their profession. It appears to us that if engineering is to be made a closed profession, practically the only organized body which could with any degree of safety undertake to pass upon the fitness of candidates to practice their profession would be the National Engineering Societies.

"Engineering" plainly declares that with a definite examination made a requisite to entrance to the Institution of Civil Engineers, there is little doubt that Parliament will give to that body the legal authority to regulate the practise of Civil Engineering in Great Britain, whenever it may be asked to do so. We had not supposed that the task was so near being undertaken in earnest on the other side of the water; but if this is the case, American engineers will watch with no small degree of interest the progress of this movement there and may learn some valuable lessons from the experience of their British brethren.

Aside from the question of legal restrictions upon entrance to the profession, the provision for examination and thesis work as a preliminary to entrance to the Institution appears to us a very desirable change and a welcome evidence that this great and honorable society is not running in a rut, but is endeavoring to keep abreast of the changes in modern conditions which are going on.

The requirement of thesis work especially appears to us to be a recognition of a fact that a liberal education is now quite as essential to the success of an engineer as it is in other professions, and the ability to write a clear-cut, well-expressed paper upon some engineering subject is almost as requisite as is the knowledge necessary to perform the work itself. An engineer has to deal with the community at large as well as with the workmen under his charge; he has to make investigations and report upon large projects, and he should be trained to think logically and express himself clearly. If he enters upon the practice of his profession without this training, he will rarely find time to acquire this knowledge afterwards, and he will be handicapped to that extent throughout his professional life. Exceptional men in the past have by sheer force of natural ability risen to eminence in the profession of engineering in spite of their lack of educational advantages, and some men may do so again; but men of this type are rare, and when the average man is to be considered he needs all the education and careful training that he can secure.

LETTERS TO THE EDITOR.

The Design of the Gray Column.

Sir: In my letter published in your issue of April 8 I find that in making an effort to be brief I appear to make a statement that is obviously incorrect. The tie-plates in the Gray column will transmit shear. The question is as to the amount. Referring to Mr. Gray's illustration in the same issue, if we select for examination a 14-in. square column, 12 ft. long, composed of eight 6 × 3½ × ½-in. angles, we find by the table in Gray's "Manual," p. 6, that this column will carry with safety a concentric load of 535,000 lbs. Using the data given in this table, and assuming that a ¾-in. rivet in single shear will safely transmit 4,000 lbs., we find the shear that may be safely transmitted by each tie-plate by taking moments about the intersection of the center line of the plate with the center line of the rivets, thus:

$$\frac{2 \times 3 \times 4{,}000}{6.3} = 3{,}810 \text{ lbs.}$$

Now, if there are ten tie-plates riveted to each pair of angles, the total amount of shear that may be safely transmitted is 38,100 lbs., which is less than 7.1% of the safe working load of the column as given in Mr. Gray's manual. If we look at the figure in Mr. Gray's letter, showing the section of the column, we will see that the line of stress is at an angle of 45° with the axis of the rivets, hence the rivets are not in pure shear, but are practically in tension, and consequently the amount of shear that may be safely transmitted must be very much reduced. If we select a longer column for examination the result is still less favorable. Yours, etc.,

Architectural Engineer.

Chicago, Ill., April 12, 1897.

The Mississippi Levees.

Sir: The present flood in the Mississippi River and the numerous instances in which the levees have failed, and will probably fail, should cause a discussion as to the proper manner of constructing them.

What is the object for which the levees are constructed? Primarily, to keep the river from overflowing the adjacent lands; and, secondly, to confine the waters, so that they will scour and deepen the channel.

To build a thoroughly good levee it is necessary to combat and overcome the elements which tend to destroy it. These are: (1) The hydraulic pressure. (2) The wave wash. (3) The ravages of crawfish and muskrats. (4) Saturation from long-continued floods. None of these are especially dangerous except the last, for unless the levee is saturated none of the others can have disastrous effect. If the levee is hard and compact, the crawfish and muskrats will not penetrate it, the waves will not wash it, nor the pressure overturn it.

The great trouble with the levees arises from the material of which they are built and the manner of doing the work. The material in most cases, so far as I know in all cases where levees have failed, is river silt and sand, thrown up with scrapers and wheelbarrows. It is a notable fact that where the scrapers have been used, the levees stand much better than where they have been built by wheelbarrow work.

What intelligent engineer would attempt to build a wall around a reservoir of loose earth, and yet what difference is there in essentials? The ideal levee is one that has a front of sheet piling, which will be impervious to water, crawfish and wave wash, and so will not interfere in the slightest degree with the navigation of the river.

Instead of giving a slope of 3 to 1 on the river side, which is nowadays a very usual practice in high levees, it can be made perpendicular, and only such an amount of material need be placed in the rear as will sustain the hydrostatic pressure. Respectfully,

P. H. Thomson, Asst. Engr.

U. S. Engineer's Office, Plaquennie, La., April 10, 1897.

Explosion in the Tunnel Under Lake Michigan.

Sir: In your issue of April 8 you make reference to "An Explosion in the Tunnel Under Lake Michigan, at Chicago," and state that the cause is supposed to be due to natural gas which accumulated in the tunnel. Permit me to state that there was no accumulation of gas, nor could there have been under the circumstances. There being no accumulation of gas, the explosion must have been due to some other cause.

The gas occasionally encountered in tunnel construction here is similar to marsh gas; and its presence is frequently coincident with the uncovering of torpedo sand pockets. When the presence of gas is suspected a test for it is made by placing a lighted candle upon the end of a 10-ft. pole, carrying it to the supposed location of the gas

vein; and if correct the gas is ignited, burning for a few minutes. This operation is attended with no more danger than the igniting of a jet of gas emanating from a pipe. This process of burning the gas prevents its accumulation and the consequent danger of explosion from that cause. Operations are continuous during the 24 hours of each day, there being two mining shifts and one mason shift during that period.

The cause of the accident referred to was undoubtedly due to the striking of an unexploded dynamite cartridge by a pick in the hands of one of the miners, who met his death at the time. The material of the section is a hard clay. Other circumstances in connection with the accident indicate the correctness of this conclusion.

Very truly,

Howard H. Jackman, M. Am. Soc. C. E.
Asst. Engineer for the City on the Work.
112 N. Humboldt St., Chicago, April 10, 1897.

(That the cause of the explosion was the striking of an unexploded cartridge, as our correspondent states above, has now been affirmed by the verdict of the coroner's jury. Without reference to this particular accident, however, it is by no means made clear to us by the above letter that the method of testing for the presence of gas on which we commented is not a dangerous one.

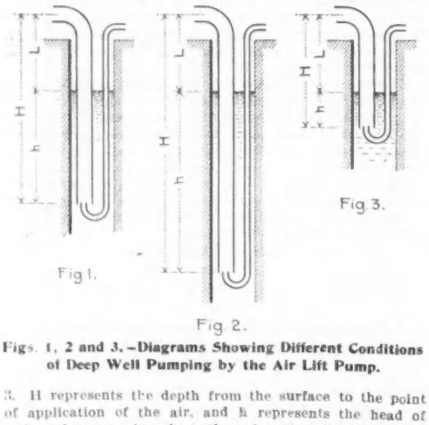
The igniting of a jet of combustible gas emanating from a pipe in an enclosed chamber such as a room or a tunnel is highly dangerous, if the gas has been escaping for some time before the light is applied. It is not uncommon for an explosion to take place in the cellar of a dwelling-house when the housekeeper takes a lighted candle to search for a leak in the piping. When the presence of combustible gas is suspected in a tunnel or a mine it appears to us that the only proper test for it is the exploration of the suspected area with a safety lamp.

It is doubtless true that the rough and ready means of testing for gas which our correspondent describes is in common use by old tunnel workmen and mine foremen. The indifference to dangers of this sort which workmen show is a well-known fact. Because a risky task is performed in safety ninety-nine times in a hundred, they fail to appreciate that there is any element of danger in it. But it is the duty of an engineer in responsible charge of work to save his workmen from the dangers to which they themselves are oblivious, so far as it is in his power so to do.—Ed.)

Theoretical and Practical Limitations of the Air Lift Pump.

Sir: The growing use of compressed air as a means of raising water from deep wells, and its extensive heralding as an economical mechanism for this work, warrants a somewhat more complete investigation of its merit than has been made public. The short time that has elapsed since the first commercial introduction of this method is doubtless the chief factor in the veil of mystery concerning its action which surrounds it, even in the minds of engineers well acquainted with hydraulic work.

To set forth clearly the theoretical and practical limitations of this system let us first examine Figs. 1, 2 and 3. H represents the depth from the surface to the point of application of the air, and h represents the head of water when pumping above the point of application of the air; L represents the lift against which the water is pumped.



Figs. 1, 2 and 3.—Diagrams Showing Different Conditions of Deep Well Pumping by the Air Lift Pump.

Stripping the problem of all its outward conditions, it will be seen that the air lift pump, the same as any other pump, must operate by displacement. In a piston or plunger pump this displacement is gained by the pushing of the resisting body of water through a certain stroke of the plunger determined by the mechanism employed, the work done per stroke of the plunger being evidently the product of the weight of water lifted into the head against which it is lifted. Therefore, in considering the air lift it will be seen that in order to displace a cubic foot of water at the point of application of the air, a cubic foot of air has to be forced into the discharge pipe. The conditions governing the quantity of air used will be clearly shown in the figures. In Fig. 1, which represents about normal conditions, h is about 0.6 of H; theoretically it should be 0.5 of H, the reason obviously being that the pressure at the point of application of the air due to the head, h should be equal or slightly in excess of the pressure in the discharge pipe at that point, this latter being a function of the specific gravity of the column, which, in the case under consideration, if h is equal to L, will be 0.5 or slightly less. Obviously, under these conditions, the least quantity of air is used, as its power used is utilized by its displacement only.

Fig. 2 illustrates the conditions of excessive submergence, the point of application of the air being carried to a greater depth than is necessary. The head h against which the air may discharge being in excess of that which is required, and the specific gravity of the column due to H being greater than is necessary, the result is that the air is used under greater pressure than would otherwise be necessary, and the excess of power required to compress it is wasted. Fig. 3 illustrates the other extreme of the conditions where h is less than the head required to maintain the proper specific gravity of the discharge column, the kinetic energy of the entering air being utilized in part to overcome the difficulty, obviously causing an increase in the use of air.

Passing now from the consideration of the conditions under which the air is discharged we will assume that in practice it is discharged at a pressure which equals the pressure due to the discharge head; conditions which cannot be put in practice, but which are sufficiently accurate for practical purposes, and which are certainly fair in consideration of the problem. "Table I." shows the theoretical horse power that is required:

(1) To lift 1 cu. ft. of water per minute from any depth to 300 ft.

(2) The theoretical horse power required to deliver 1 cu. ft. of air per minute when the air is compressed isothermally; that is, without change of temperature.

(3) The theoretical horse power required to deliver 1 cu. ft. of air per minute with air compressed adiabatically or without cooling, these two tabulations to 100 lbs., gage being taken from Richard's work on "Compressed Air."

(4) The theoretical horse power required to deliver 1 cu. ft. of air per minute with two-stage compression, the assumption being that the power required is a mean between that for isothermal and that for adiabatic compression. As a cubic foot of air is required to displace a cubic foot of water, the power required to deliver a cubic foot of air per minute is the equivalent of the power required to deliver a cubic foot of water per minute from the same depth or against the same pressure.

The comparison of column 3 with columns 4, 5 and 6 shows the excess of power required to compress the necessary air, and a ratio comparison of these gives the theoretical efficiency that may be obtained with the air lift only, considering that the air lift as a machine has an efficiency of 100% and that the compression is accomplished under the conditions named for two-stage and single-stage compression, no account of the mechanical efficiency of the compressor itself being taken into consideration. It will be seen that the power required to deliver isothermal air is left out of consideration in this table, the reason being that the conditions for such compression are impossible to find in actual service. From inspection of the table it will be seen, therefore, that the maximum efficiency possible in delivering water to a height is below suction distance ranges from 68% for [illegible] compression and 64% for single-stage compression, at a depth of 34 ft., to 32% and 28% respectively, with a lift of 300 ft.

The problem as considered thus far involves only the theoretical power required to deliver the necessary volume of air only. From the best results that have been obtained in compressor service it is fair to assume that the single-stage compressor, considered as a machine, with an efficiency of 51% at 35 ft. may be obtained an efficiency of 51% power developed by the steam end to that represented by the cooled air delivered into the receiver from the air end. For two-stage compression 75% represents similar practice. The product of the air lift and compressor efficiencies, "Table II.," gives the resultant efficiency of the apparatus. We find that for two-stage compression an efficiency of 50% at 35 ft. may be obtained at 247 at 300 ft. For single-stage compression we find [illegible] is the highest limit at 35 ft. lift, and 17% at 300 ft. The diagram, Fig. 4, shows graphically the maximum theoretical efficiencies as developed from "Table II." From an inspection it is evident that except for small lifts the efficiency is very low, much lower than is demanded by good practice in any line of pumping machinery. To get the subject of the power required clearly defined, the diagram, Fig. 5, is laid out from Tables I. and II. Comparison between the theoretical horse power to lift water, and the power required by the air lift shows that the adoption of the latter must be urged by other reasons than its economy.

The matter of duty is one which may easily be computed from the data shown in the diagram, Fig. 5. In the duty "Table III." is shown a range of water economy for the compressor engines sufficiently large to meet the conditions of practical service, thus, for example, with 20 lbs. of water consumed per horse power hour with two-stage compression it is possible to produce a duty of 51,000,000 ft. lbs. with a lift of 35 ft., and 24,100,000 ft. lbs. with a lift of 300 ft., and with single-stage compression 38,600,000 ft. lbs. and 16,300,000 ft. lbs. respectively, at the same depths. There can be no doubt but that for some situations the air lift has peculiar advantages, but its inherent lack of economy places it out of the range of good engineering practice for all ordinary problems of water supply from deep sources.

In diagram 2 the position marked "A" at 85 ft. lift shows graphically the result of the air lift machinery at Rockford, Ill., the complete data of which were published in Engineering News of March 4, 1897. At "B," depth 282 ft. is shown the result from another class of deep well machinery, the comparative efficiency of which will be easily understood by referring to the diagram.

E. E. Johnson, M. Am. Soc. M. E.
61-69 North Jefferson St., Chicago, Ill., April 3, 1897.

Test of the Cahall Boiler at the Armstrong Cork Works.

Sir: A copy of your issue of March 18 was sent to me here, while I was several hundred miles away at my work, and to some of your criticisms on p. 169 of that article I shall ask space in the same way to show pretty clearly that what has in proper work been done cannot be classed "impossible" with regard for the truth by your writer.

TABLES SHOWING THEORETICAL HORSE POWER REQUIRED TO OPERATE, AND POSSIBLE EFFICIENCY AND DUTY OBTAINABLE FROM, THE AIR LIFT PUMP AT DEPTHS FROM 5 FT. TO 300 FT.

TABLE 1						TABLE 2					TABLE 3										
LIFT IN		THEORETICAL HORSE POWER				EFFICIENCY OF AIR LIFT					MAXIMUM DUTY OBTAINABLE WITH AIR LIFT.										LIFT IN
			TO DELIVER ONE CUBIC FOOT OF AIR PER MIN.			THEORETICAL			TOTAL FROM POWER APPLIED TO WATER DEL.		WATER ECONOMY OF COMPRESSOR ENGINE										
											TWO STAGE		SINGLE STAGE								
LBS. PRESS	FEET HEAD	TO LIFT ONE CUBIC FOOT OF WATER PER MIN.	ISOTHERMAL	TWO STAGE	ADIABATIC	ISOTHERMAL COMPRESSION	TWO STAGE COMPRESSION	SINGLE STAGE OR ADIABATIC COMPRESSION	TWO STAGE COMPRESSION	SINGLE STAGE OR ADIABATIC COMPRESSION	20 LBS	25 LBS	30 LBS	20 LBS	25 LBS	30 LBS	35 LBS	40 LBS	45 LBS	50 LBS	FEET HEAD	LBS PRESS
5	11.54	.02153	.02814	.02572	.0263	.87	.848	.83	.623	.497	61.8	49.5	41.1	49.2	39.3	32.7	28.1	24.6	21.8	19.7	11.54	5
10	23.09	.04363	.05586	.05952	.064	.78	.728	.684	.546	.41	54.2	45.5	36.2	40.6	32.5	27.	23.2	20.3	18.1	16.3	23.09	10
15	34.63	.06545	.09105	.0962	.1015	.72	.687	.648	.515	.369	51.	40.7	34.	38.6	30.8	25.6	22.	19.3	17.1	15.4	34.63	15
20	46.20	.08727	.12994	.1391	.1483	.675	.627	.59	.47	.354	46.5	37.2	31	35.	28.	23.3	20.	17.5	15.6	14.	46.20	20
25	57.75	.109	.17191	.1857	.2004	.635	.575	.545	.432	.327	42.7	34.2	28.5	32.4	25.9	21.6	18.5	16.2	14.4	13.	57.75	25
30	69.31	.13091	.21678	.2370	.2573	.603	.548	.508	.412	.305	40.7	32.6	27.1	30.2	24.2	20.1	17.3	15.1	13.4	12.1	69.31	30
35	80.86	.1527	.26445	.2915	.3187	.577	.52	.478	.39	.287	38.6	30.8	25.7	28.4	22.7	18.9	16.2	14.2	12.6	11.4	80.86	35
40	92.41	.17454	.31376	.3489	.3842	.557	.502	.455	.376	.273	37.2	29.8	24.8	27.1	21.7	18.1	15.5	13.5	12.1	10.8	92.41	40
45	103.90	.1963	.36565	.4085	.4538	.540	.482	.435	.362	.260	35.8	28.6	23.9	25.8	20.6	17.2	14.7	13.	11.5	10.3	103.90	45
50	115.50	.21818	.41848	.4722	.5261	.522	.464	.415	.348	.249	34.5	27.6	23.	24.7	19.7	16.4	14.1	12.4	11.	9.9	115.50	50
55	127.00	.24	.47112	.5366	.6025	.51	.447	.40	.336	.24	33.2	26.6	22.1	23.8	19.	15.8	13.6	11.8	10.6	9.56	127.00	55
60	138.60	.26181	.52855	.6051	.6818	.495	.432	.384	.324	.231	32.	25.6	21.3	22.9	18.3	15.3	13.2	11.8	10.2	9.15	138.60	60
65	150.10	.2836	.58612	.6734	.7608	.485	.422	.372	.316	.223	31.3	25.	20.9	22.1	17.7	14.7	12.6	11.1	9.85	8.85	150.10	65
70	161.70	.30545	.64812	.748	.8463	.471	.408	.36	.307	.216	30.4	24.3	20.2	21.4	17.1	14.3	12.2	10.7	9.6	8.55	161.70	70
75	173.30	.3273	.70952	.823	.9386	.462	.398	.35	.299	.210	29.6	23.9	19.9	20.8	16.7	13.9	11.9	10.4	9.25	8.32	173.30	75
80	184.80	.3491	.76543	.898	1.0291	.455	.39	.345	.292	.206	28.9	23.1	19.3	20.4	16.3	13.6	11.6	10.2	9.05	8.15	184.80	80
85	196.30	.37	.83039	.976	1.1231	.446	.38	.331	.285	.198	28.2	22.6	18.8	19.6	15.7	13.1	11.2	9.8	8.7	7.85	196.30	85
90	207.90	.3927	.89444	1.055	1.2176	.439	.373	.324	.28	.194	27.7	22.2	18.4	19.2	15.4	12.8	11.	9.6	8.52	7.65	207.90	90
95	219.40	.4148	.96164	1.137	1.3148	.431	.368	.315	.276	.189	27.3	21.8	18.2	18.7	14.9	12.8	10.7	9.35	8.3	7.5	219.40	95
100	230.90	.43636	1.0243	1.247	1.4171	.428	.362	.308	.264	.185	26.1	20.9	17.4	18.3	14.6	12.2	10.5	9.2	8.15	7.3	230.90	100
110	254.10	.48	1.162	1.394	1.626	.413	.346	.296	.26	.177	25.7	20.6	17.1	17.5	14.	11.7	10.	8.75	7.76	7	254.10	110
120	277.20	.5236	1.301	1.571	1.841	.402	.333	.293	.25	.171	24.6	19.3	16.5	16.9	13.5	11.3	9.65	8.45	7.5	6.75	277.20	120
130	300.40	.5675	1.443	1.765	2.068	.394	.324	.275	.243	.165	24.1	19.3	16.1	16.3	13.1	10.9	9.3	8.2	7.25	6.5	300.40	130
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	2	1

ing that no intimation of possible error was expressed in Mr. Pray's report."

The tests of the "Cahall Patent Boiler in the Armstrong Cork Company's yard at Pittsburg" was conducted by the writer, but subject to certain restrictions as to not interrupting the regular work of the concern, which compelled the using of the "alternative method" of the A. S. M. E. Code.

The tests for economy and capacity were both made under alternate method, and in my report it reads clearly that this is a matter of uncertainty in final result, and to what extent is not known to the writer. It was not considered as of any vital importance, so far as efficiency went, nor capable of changing results to an appreciable extent.

I now quote from your own p. 169—"For Mr. Pray, Mr. Pray does not in his report at any place state that the results chemically or otherwise are absolutely accurate, nor does Mr. Pray state that he has computed any of these results in any other way than according to the most generally used as well as acknowledged standard, and the names signed to that code or method, in the original proceedings, show that those who signed it are responsible.

It would seem that my critic has not noticed the computation, or possibly considers that such a boiler could not superheat at all its steam during the whole day's work to an extent which goes far to prove the value of it as a "steamer" and it is not often found to be the case—as stated, that portion of the performance is a fact.

While there is a room for doubt on the basis of usual computation outside of the A. S. M. E. Code that some above described, the following may be employed where local conditions render it necessary:

At the regular time for slicing and cleaning fires have them burned rather low, as is usual before cleaning, and then thoroughly cleaned; note the amount of coal left on the grate as nearly as can be estimated; note the pressure of steam and the height of the water level—which should be at the medium height to be carried throughout the test—at the same time; and note this time as the time of starting the test. Fresh coal, which has been weighed, should now be fired. The ash pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave the same amount of fire, and in the same condition, on the grates as at the start. The water level and steam pressure should be brought to the same point as at the start, and the time of the ending of the test should be noted just before fresh coal is fired.

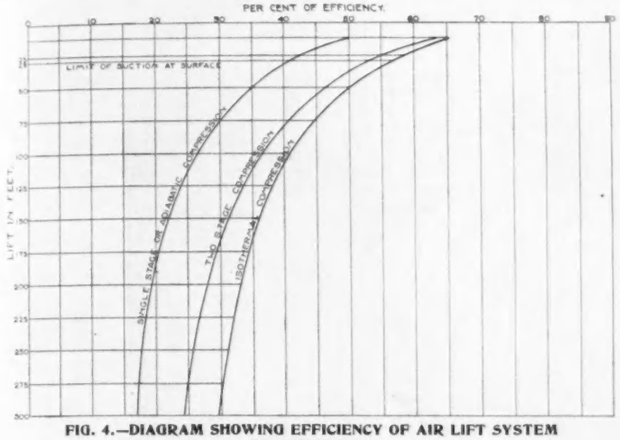

PER CENT OF EFFICIENCY.
LIMIT OF SUCTION AT SURFACE
LIFT IN FEET.
SINGLE STAGE OR ATMOSPHERIC COMPRESSION
TWO STAGE, COMPOUND SUCTION
TWO STAGE, COMPOUND SUCTION AND COMPRESSION

FIG. 4.—DIAGRAM SHOWING EFFICIENCY OF AIR LIFT SYSTEM OF PUMPING.

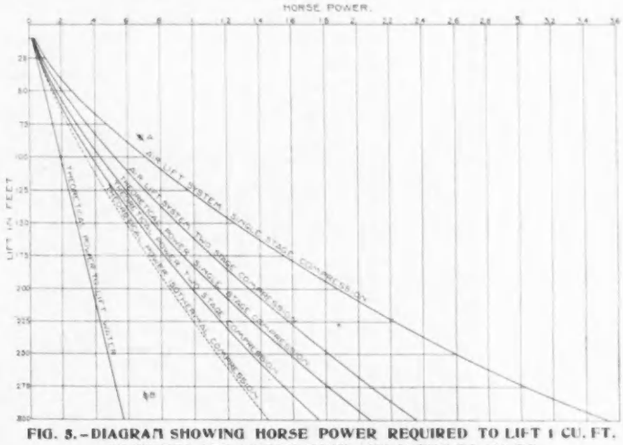

HORSE POWER.
LIFT IN FEET
AIR LIFT SYSTEM, SINGLE STAGE COMPRESSION
AIR LIFT SYSTEM, TWO STAGE COMPRESSION
CENTRIFUGAL PUMPS, SINGLE STAGE, LOW SPEED, DIRECT CONNECTED
CENTRIFUGAL PUMPS, SINGLE STAGE, HIGH SPEED, BELT CONNECTED
RECIPROCATING PUMPS, TRIPLE EXPANSION, CONDENSING
RECIPROCATING PUMPS, COMPOUND, CONDENSING
RECIPROCATING PUMPS, SINGLE EXPANSION, NON-CONDENSING

FIG. 5.—DIAGRAM SHOWING HORSE POWER REQUIRED TO LIFT 1 CU. FT. OF WATER PER MINUTE FROM ANY DEPTH TO 300 FT.

himself, however, it is difficult to see what excuse can be made, etc."

In the first place, let us see if necessity for excuses for Mr. Pray exist. Your critic takes the position that my figures of 13.968 lbs. of water at and from 212° F. are impossible—if it is read rightly by me. It is here necessary to digress for a moment, in order that what follows shall be clearly and unequivocally considered.

It is taken for granted that your critic had a copy of my reports at hand, or, if not, allow me to copy verbatim from first page of same under "General reference to items of all the tests," third paragraph, and over to top of second page:

The different reports are all figured upon precisely the basis of the Code of the American Society of Mechanical Engineers for tests, embodied in Article CLXVIII., Vol. VI., transactions of its society. Some of the items which are added here are tabulated in conformity to my usual practice, as being slightly more explanatory, and very full data for any reference of the figures by any party desired.

If the committee who drew the plan of the code adopted and above referred to have made any mistakes, it is not the fair thing to blame "Mr. Pray" for that.

Items needed for the computation taken from the report are as follows:

Page 6.

Item 16	—Coal from the pile, in lbs.	7,138.
" 17	—Moisture in coal, %	2.0134
" 17a	—Moisture in coal, in lbs.	143.72
" 18	—Dry coal, in lbs	6,994.28
" 19	—Ash and cinders, lbs.	1,271.5
" 19a	—Ash and cinders %	18.18
" 19b	—Pounds of moisture, ash and cinders	1,415.22
" 19c	—Total loss in coal, all causes, %	19.827
" 20	—Pounds of combustible	5,722.78

Omitting items 21 and 22 and proceeding at once to the Calorimeter results and we have:

Item 23	—Quality of steam (dry steam being taken as unity)	1.02184
" 24	—Percentage of moisture in steam	0.0000
" 25	—Number of degrees of superheat, F.	40.238
" 25a	—Percentage of superheat	2.184
	Water.	
" 26	—Total water pumped, etc., as per code.	65,949 lbs.
" 27	—Water, etc., corrected for superheat.	67,388 lbs.
" 28	—Equivalent water at and from 212° F.	79,936 lbs.
" 28a	—Factor of evaporation	1.1862

Omitting numbers 29 and 30 of the code and the results to which you except as "impossible" are reached.

Economic Evaporation.

Item 31	—Water actually evaporated per lb. of dry coal from actual pressure and temperature	9.6347 lbs.
" 32	—Equivalent water evaporated per pound of dry coal from and at 212° F.	11.429 lbs.
" 33	—Equivalent water evaporated per pound of combustible at and from 212° F.	13.968 lbs.

The items above are those intimately connected in my computations, and I would now thank your critic to point out any error on my part, either in following the directions laid down in the code named, as to process, or in numerical computation of result so far as the figures go, and it will be promptly acknowledged if you are able to point out any errors as stated.

question may exist as to correct determination of B. T. U. in one pound of coal as capable of 13.968 lbs. at and from 212°—for that amount of water calls for less than 14,000 B. T. U., which is not very high with over 2% added in superheat of steam in correction and over 18% of total refuse—and would seem to imply the possibility of a correction of your word "impossible."

It is a fact, as named in the report, that there were peculiar atmospheric conditions present during that day, not in favor of the boiler doing its average work, and equally true that one of the most peculiar firemen ever seen by the writer was in charge of the fires, and also true that a strong protest from me was made to the Manager of the Cahall Sales Department, that the "Hawley Down Draft Furnace" on that day, and on the day of the capacity test, was badly mismanaged. I believed then and do to-day that outside influences were present then to injure that day's results, and yet my own insistence and refusal to leave one minute kept this at a minimum, and the result is as given to the figures in that report, with not a doubt in my own mind that with ordinary atmospheric conditions, more reason in the firing, and decidedly more brains used in the management of the upper and lower doors of that furnace, repetition of the test is certain to somewhat increase the results, and truthfully.

The Cahall Boiler has capacity to utilize its heated gases, and upon heating surfaces admirably arranged its actual efficiency as given at 85.862% is high, and so far as the A. S. M. E. Code goes that amount is a straight statement of its doings on the day and date "aforesaid."

You will please accept my thanks for your courtesy, and excuse me from following into the question of the gases, where you "assume," and I trust will also forgive the length of this, but it can hardly be accepted as my opinion or another's. Facts are unelastic, and a discussion of all of them is what we are after. Very truly yours,

Thomas Pray, Jr.

95 Milk St., Room 71, Boston, Mass., April 9, 1897.

We are indebted to Mr. Pray for a printed copy of his report of the test made at the Armstrong Cork Works, in addition to the above letter, with some portions of it marked for our special attention. In one of these portions, which we quote below, we find evidence to confirm the opinion expressed in our issue of March 18, in addition to the reasons therein given, that the result reported, viz., 13.968 lbs. of water evaporated from and at 212° per lb. combustible, is erroneous. It will be noted that in his letter Mr. Pray states that he used the "alternative method" of the A. S. M. E. Code. This "alternative method" is one of the methods given in the code for starting and stopping a test. We quote it from Trans. Am. Soc. M. E. as follows:

XI. Alternate Method.—Instead of the standard method

Mr. Pray's method of starting and stopping the test is thus described in his report:

The fires were sliced or cleaned in the upper grate; the lower grate was also supposed to be clean or freed from any dirt or refuse matter and the ash pit cleared. The fire was then fed with fresh coal to bring it up to the fireman's idea, after which the observations were commenced, and every 15 minutes by the clock; and all observations were taken precisely on the moment, without waiting for any reports or conditions to change, and this was followed without any exception or qualification to the end of the test. At the end of the test the fire was re-fed precisely as at the commencement, and it was my intention to leave the fire in the same condition as it was found or better, preferring to put the boiler at a disadvantage.

It will be observed that in the code explicit directions are given for noting the time of starting the test just before feeding fresh coal and after noting the amount of coal left on the grate after cleaning, the fires previously having been burned low, as is usual before cleaning, while Mr. Pray, on the contrary, noted his time of starting after the fire was "fed with fresh coal to bring it up to the fireman's idea." At the end of the test the code states that the time of ending should be noted just before fresh coal is fired, the fires having been burned low and cleaned. Mr. Pray's ending was after fresh coal had been fed, "precisely as at the commencement." The essential difference between the method of the code and that of Mr. Pray is that by the former the judgment of the testing expert as to the amount of the coal on the grate is made both at the beginning and end of the test at the time when its quantity is the least, that is, after burning low and cleaning, so that any error made in the judgment of the quantity and condition of the coal left on the grate is likely to be only a small percentage of the total amount of coal used during the whole test, while in Mr. Pray's method the judgment is made after sufficient fresh coal has been fed to bring the fire "up to the fireman's idea," that is when probably the maximum quantity of fresh coal is on the grate. An error in judgment of this large quantity is apt to amount to a considerable percentage of the total coal. The method of Mr. Pray is open to all the objections raised against the old fashioned "flying start and stop," which is now generally condemned by testing experts.

Mr. Pray in his letter states that the test was made under unfavorable conditions, and that he believes that a repetition of it "is certain to somewhat increase the results." As four other economy tests were made by four different experts, their average result being 11.492 lbs., Mr. Pray's result, 13.968 lbs. being over 21% higher, we think it

likely that a repetition of the test will show that he is mistaken. From the data we have thus far received we are unable to form any other opinion than that we have already expressed. We will be glad to revise it if we can obtain more data, and if Mr. Pray will kindly furnish us a copy of his log of the test, together with the complete report of the analysis or calorific test of the coal, we will take pains to study it, and give our conclusions based upon such study.

If there is any possibility that Mr. Pray's test is accurate it behooves the whole boiler fraternity to inform themselves of it, and find out how such results can be obtained. If it is possible to get out of Pittsburg coal 20% higher evaporation than was ever before obtained, and 30% more than is obtained in every day practice, the improvement of steam boilers, furnaces or methods of firing by which this result can be regularly accomplished will be a most important advance in steam engineering. It would be interesting, also, to know why the four other experts got results so far below those reported by Mr. Pray.—Ed.

THE NEW 550-FT. STEEL ARCH RAILWAY BRIDGE OVER THE NIAGARA GORGE.

The two halves of the great 550-ft. steel arch bridge now being constructed at Niagara Falls, N. Y., to replace the old railway suspension bridge, first erected by John A. Roebling in 1855, were joined at the center on March 30, barely two months from the date the first riveted member of the arch was placed in its permanent position. This work, it should be said, yet leaves the erection of the total 7,200,000 lbs. of steel in the structure far from completion, there remaining a large amount of riveting and other work on the main arch members, besides the double floor construction and a variety of collateral work in removing the old bridge and finishing the new span ready for traffic. With the completion of the center connection, however, the structure has reached a stage of completion which enables a very fair idea of its size and appearance to be had, and we therefore present the accompanying engravings from photographs recently taken and furnished us by the Pennsylvania Steel Co., the contractors, and Mr. R. S. Buck, Resident Engineer, in charge of the work.

In Engineering News of Aug. 6, 1896, were published the main plans and elevations and a few general details of the Niagara Falls steel arch, and for full particulars regarding its inception and character and concerning the history of the noted structure which it replaces, this article should be consulted. In order, however, to aid in the understanding of the illustrations given here, a few of the main dimensions may be repeated. The arch crosses the Niagara gorge just above where the well-known whirlpool rapids begin, and has a span of 550 ft. between springing points. The railway floor, which is above the highway floor, is 225 ft. above the surface of the water. Connecting the arch with the tops of the cliffs on either side are two 115-ft. trussed spans, and in addition there are approaches on the two shores aggregating 290 ft. in length. As already stated 7,200,000 lbs. of steel will be used in the structure, and all connections are riveted, requiring altogether 2,000,000 rivets, of which 190,000 have to be driven in the field.

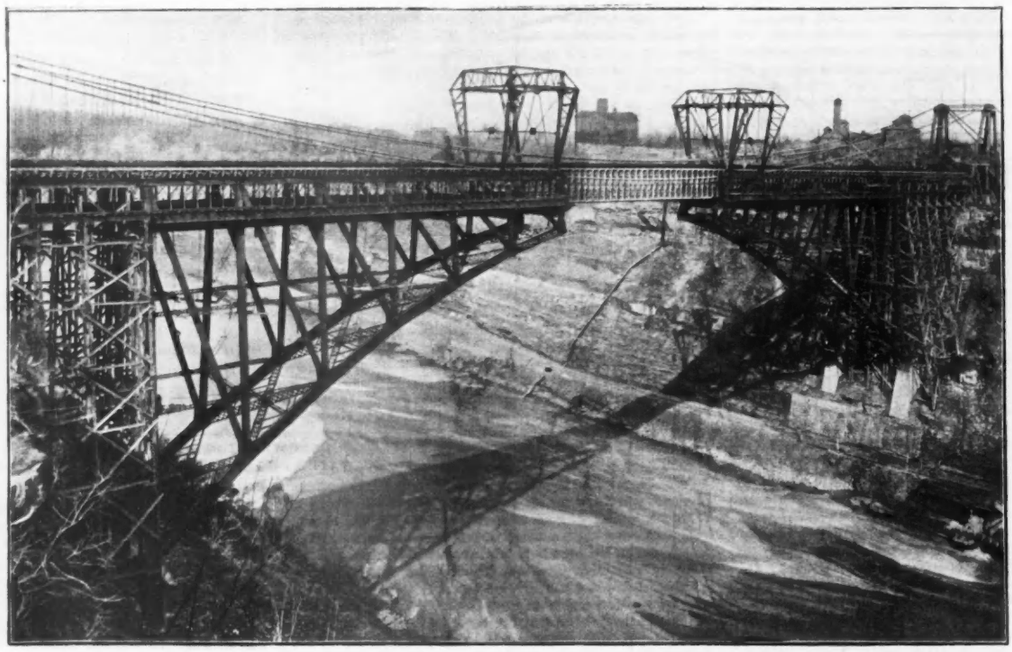


FIG. 1.—THE 550-FT. SPAN STEEL ARCH ACROSS THE NIAGARA GORGE. (Four Center Panels not yet Placed when Photograph was Taken. L. L. Buck, M. Am. Soc. C. E., Chief Engineer. R. S. Buck, Engineer in Charge. Pennsylvania Steel Co., Steelton, Pa., Contractors.

Fig. 1 shows the arch completed, with the exception of the four center panels, and gives a very fair idea of the appearance of the structure. As will be seen, the lower or arch chords spring from masonry abutments or skewbacks located part way up the cliff on each side of the gorge. Figs. 2 and 3 show the abutments on each side of the gorge and explain quite clearly their construction. Seated on and anchored to these skewbacks are the four shoes or pedestals carrying the feet of the steel arch chords. The top chord of the bridge is horizontal and is connected to the arched chord by posts and diagonals as shown. Among other features to be noticed in this general view is the stiff diagonal sway bracing between the arched chords. This stiff bracing, besides such structural advantages as it may possess, adds materially to the beauty of the arch, as becomes at once apparent to one viewing the actual structure from one side or below.

Turning now to the erection, it will be easily understood that herein was found one of the most difficult problems of the work. Both the old and new bridges are on the same center line, and the new structure had thus to be erected without disturbing traffic upon the old structure, which averages one train about every 15 minutes.

The first work was the erection of false works, consuming altogether 500,000 ft. B. M. of timber, on each side from the tops of the cliffs to the skewbacks and one panel beyond. These false works were intended to support the 115-ft. shore spans during erection and to afford a track for taking material onto the bridge during the erection of the arch. After the erection of the false work, the first work was to place the pedestals on the skewbacks. As each of these pedestals was a casting 2×10 ft. and weighed 23 tons, and as upon its exact adjustment depended in a very great measure the perfectness of the final closing of the arch, this

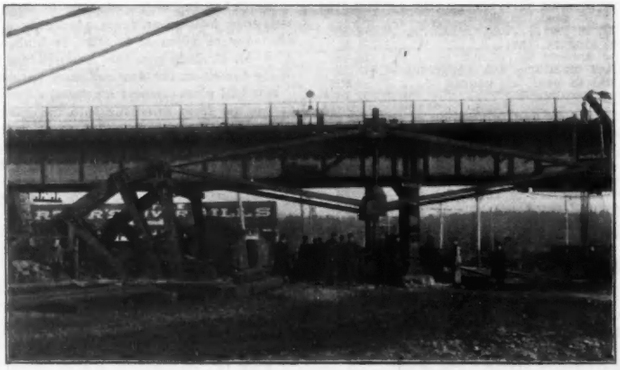


FIG. 4.—VIEW SHOWING TOGGLE JOINT FOR ADJUSTING CENTER CONNECTION OF NIAGARA ARCH.

work was of a somewhat delicate and, withal, tedious nature. The first casting, however, was lowered into position Dec. 18, 1896, and on Jan. 25, 1897, the first member of the arch proper was raised.

As the arch had no means of self-support until closed at the center, and as false works over the

Fig. 2.—View of Canadian Abutment for Niagara Steel Arch.

rapids were obviously impracticable, it became necessary to devise some means of taking the pull of the gradually extending arms being built out from the abutments. The means employed were four temporary anchorages connected by pins to the top chords and carried back to the shores, where they curved around 90° and entered 18 ft. into the solid rock, where they terminated in grillages of I-beams filled in with concrete. Just previous to the closing of the arch, when the pull of the overhanging arms was, of course, the greatest, the strain on each anchorage was 500 tons, or 1,000 tons on each side of the river. Altogether the length of each anchorage was 250 ft., and as they were merely temporary structures, to be destroyed as soon as the arch was closed, it was decided to save waste material by using in their construction the eye bars and top chord sections of the 115-ft. spans where this could be done without injury to these members. Other parts were built of such rough shapes as were convenient for the purpose.

The use of these anchorages obviously furnished possible means for raising and lowering the ends of the projecting arms, by simply introducing into each some device for increasing or decreasing its length. The device used is clearly shown by Fig. 4, and was a sort of toggle or diamond shaped frame hinged at all four corners. To each end of this frame was attached the anchor chain, or, in other words, the frame formed one link in the anchor chain. Between the top and bottom hinges of the frame was placed a right and left screw, 3½ ins. in diameter and 17 ft. long, provided at its bottom with a capstan, so that the vertical diameter of the toggle could be increased or decreased at will, thus shortening or lengthening the anchor chain and raising or lowering the end of the projecting arm. A force of twelve men to each of the four screws was sufficient to lower the arms, while four forces of 24 men each served to raise them. These toggles were operated with entire success, and, indeed, so carefully had all the work been done in placing the pedestals and building out the arms that when the anchor chains were lowered to allow the arch chord to close at the center, the rivet holes and bearing plates met within ½ in., which distance is gradually decreasing as the final load is added, until upon April 12, at the time of a visit of one of the editors of this journal, the opening measured only 3-16 in., with considerable more load to be added.

It is plain from the foregoing and the illustration Fig. 1, showing the web bracing between the top and bottom chords, that each half of the arch was built out from the shores as a cantilever. For handling the members two steel travelers, one for each arm, were used. These travelers were built of two bents, as shown in Fig. 1, and carried on their river sides two steel booms and all the necessary tackle to swing the sections into place. As each member was placed, part of the connection rivets were driven and the remainder of the holes filled with drift bolts. The tracks for material were laid on the sidewalk brackets outside of the trusses. In constructing the travelers of steel two objects were had in view, the first, of course, being strength and safety, and the second lightness, to reduce the pull upon the anchorages. Further to relieve the anchorages, the hoisting engines operating the tackle on the travelers were placed on shore and the hoisting lines run to the travelers over pulleys carried by the old suspension bridge. As the arch was completed panel by panel, the travelers were moved forward, being supported by the top chords of the new structure. To do such of the riveting as is possible by power, two portable riveting machines are to be operated by compressed air, generated by a plant on the American shore.

The next work following the closing of the arch is the construction of the floor systems. The lower floor, carrying the carriage-way and double trolley tracks, will be placed first and then the old suspension bridge truss and floor systems will be blocked up on the new bridge and removed piece by piece, to be replaced by the new structure, the old structure being for a single track and the new for double tracks. When this work is completed the four cables of the old bridge, each being 1,600 ft. long and weighing 170 tons, will be removed. The removal of the suspension bridge towers and the construction of the viaduct approaches will then follow.

The completion of this work will remove one of the old landmarks familiar to tourists to Niagara Falls. One of the most notable achievements of engineering in the world when it was first built, the old Roebling suspension bridge, as it was generally called, has twice since its construction attracted the attention of the engineering world; first when, in 1880, 25 years after its construction, the wooden superstructure was replaced by a new steel stiffening truss 820 ft. long, and second when, six years after, the old stone towers were replaced by steel ones without disturbing traffic. Both of these improvements were carried out by Mr. L. L. Buck, M. Am. Soc. C. E., the Chief Engineer of the new arch bridge. The new arch itself was made necessary by the inadequacy of the old bridge to carry the heavy locomotives and long trains rendered necessary by present conditions of traffic, without reducing both speed and length of trains during the passage. Moreover, the one track which the old bridge carried was under any conditions inadequate to the traffic. Several months will still elapse, however, before the new bridge will be ready to turn over to the railway company for use. When completed, its total cost will approximate $500,000.

As stated above, Mr. L. L. Buck, M. Am. Soc. C. E., of New York, N. Y., is the Chief Engineer of the bridge. Mr. R. S. Buck is the engineer in charge of the work at Niagara Falls. The contractors for the steelwork and erection are the Pennsylvania Steel Co., of Steelton, Pa., Mr. J. W. V. Reynders, Chief Engineer.

THE NEW HURON STREET LIFT BRIDGE, MILWAUKEE WIS.

By M. G. Schinke, Asst. City Engineer.

(With two-page engraving.)

At many of the large centers of population around the Great Lakes, navigable channels penetrate deeply into the heart of business districts. As these cities increase in size and volume of business, a constantly growing demand is felt for bridges across these channels which will accommodate the increased travel on them, as well as cut down to a minimum the obstructions to navigation and to shipping and docking facilities. The old type of swing bridge obstructs with its center pier the very best part of the channel. If the river is no wider than the swing bridge is long, its swinging circle cuts off from use by boats quite a portion of dock-space on all four corners; if for some reason or other it can only be swung in one direction, its closing or opening is often retarded by a slowly moving craft, which has to get out of the way of the swinging circle. If the bridge is made wide enough to allow two lines of teams abreast each way, the cost becomes enormous on account of the large center pier and heavy turntable required.

In the case of the Huron Street Bridge in Mil-

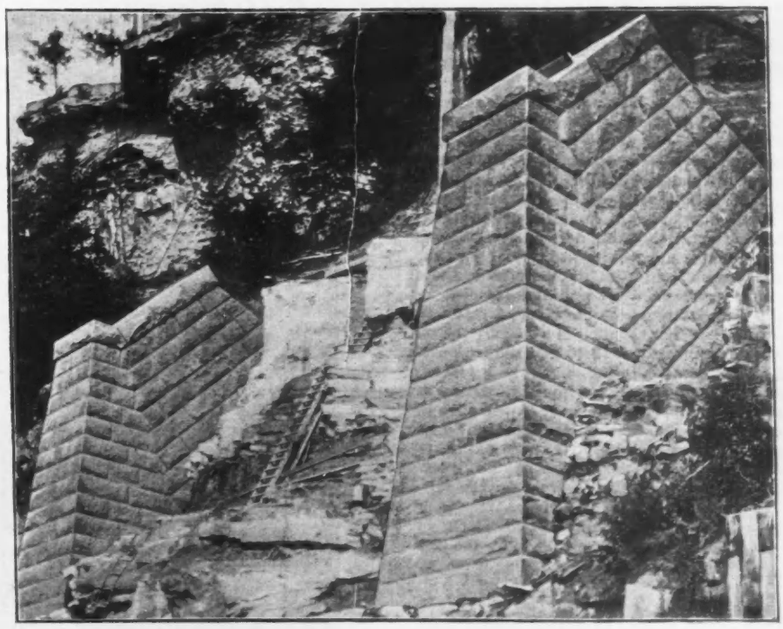


FIG. 3.—THE NEW YORK ABUTMENT FOR THE NIAGARA ARCH.

waukee, the width of the river is 220 ft. The bridge is located in the center of the business district, where a width of roadway of at least 34 ft. and 9 ft. sidewalks are an absolute requirement. The number of vessels passing through the bridge is about 25 per day, as an average of the year. This is not a large number compared with other locations, but vessels of the largest size have to be accommodated and every foot of adjoining dock-space must be made available for shipping.

FIG. 1.—GENERAL VIEW OF HURON ST. LIFT BRIDGE; DRAW CLOSED.

In order to decide upon the type of bridge to be adopted, the City Engineer, Mr. George H. Benzenberg, M. Am. Soc. C. E., made a careful study of all the questions and interests involved and finally concluded that a "lift" or center opening bridge would give the best satisfaction for the locality. Plans were made in the winter of 1895-1896, and the work was divided into two contracts, one for the substructure and one for the superstructure.

The substructure consists of two abutment-walls, about 80 ft. long, and four piers 10 ft. by 25 ft. in plan. All of the masonry rests on piles, the solid strata to which the piles are driven being about 57 ft. below datum. Piles under the abutment walls are cut off 5 ft. below datum to receive the grillage; the bottom of the masonry is 3½ ft. below datum. The abutment walls are held in place against the earth pressure by anchor rods, bearing on anchor piles driven about 24 ft. back of the abutment.

The four piers consist of Portland cement concrete blocks, 10 to 25 ft. in plan and 10 ft. high, resting on a timber grillage, for which the piles were cut off 15 ft. below datum. The concrete is surrounded by Wakefield sheet piling 8 in. thick. Considerable trouble was experienced in getting this sheeting tight for the work in the interior, the water being 17 to 18 ft. deep in the channel and the sheeting apparently too light for the water pressure. The top of the piers is one foot above datum, and their upper part is formed by three courses of Menomonee limestone, 3 ft. 6 ins. thick altogether. The sheeting is held in place by an oak wale-streak, 6 by 12 ins. in section, well secured at the corners. The work is protected at the corners by four heavy clumps, consisting of ten piles each, and by three rows of fender piles in front, with intermediate timbers, the front row of piles reaching as high as 8 ft. above datum to guard the ironwork of the bridge against overhanging parts of boats. The contract for the substructure was let to the lowest bidder, Wm. Forrestal, at a price of $24,300, and was completed to receive the iron work on the west side by the end of September, 1896, and on the east side a month later.

The superstructure consists of two stationary approach-spans, 87 ft. and 42 ft. long respectively, and two equal parts of a lift-span each 46 ft. long. The clear width of roadway is 34 ft., the clear width of sidewalks on the stationary parts is 9 ft., on the moveable parts 7 ft. The grade of the roadway is slightly ascending towards the middle, where it is 13.5 ft. above datum. The roadway has a crown of 3 ins. There is a platform projecting beyond the sidewalk on the northwest corner of the east approach and one diagonally opposite on the west approach to carry the bridge houses and also to form the stands for the men operating the bridge.

The roadway of the stationary parts is formed by 7-in. cedar blocks resting on two layers of long leaf yellow pine planking, 1 in. and 4 ins. thick. The roadway of the movable parts consists of two layers of white oak planking, 2 ins. and 3 ins. thick. The sidewalk planking is 2-in. white pine. The uniformly distributed live load was assumed at 100 lbs. per sq. ft. of roadway, and 80 lbs. per sq. ft. of sidewalk; the concentrated live load consisted of two street cars weighing 18 tons each and moving side by side on tracks 8 ft. apart c. to c. The allowed unit-strains on steel were:

Tension in bars.....14,000 lbs.
Tension in plates and shapes.....12,000 "

Compression in members with square bearings:

$$\frac{10{,}000}{1+\frac{L^2}{36{,}000\ R^2}}$$

Compression in members with pin bearings:

$$\frac{10{,}000}{1+\frac{L^2}{18{,}000\ R^2}}$$

Shearing ..... 9,000 lbs.
Bearing ..... 12,000 "

All steel was inspected at the mill. First class shop work was required, all rivet holes to be reamed out ⅛-in.

The stationary parts, spanning the space between the abutment walls and piers were designed as plate girder deck-spans. The lift-span, designed by the writer, may be briefly described as follows: A triangular supporting girder, anchored at its rear end into the masonry, carries a pair of rollers on its top and forward end, which support the rear end of the main girder. The forward support of the main girder is formed by a swinging strut pin-connected to it at the upper end and to the base of the triangular girder at the lower end. The main girder is double under the rear and middle panel. Each of the two parts for the rear panel is provided with a curved track, which runs on the supporting rollers when the bridge is swung. The whole movable part is counterweighted so as to bring the center of gravity to a certain point (marked on drawing) and the curved track is laid out so that this point moves in a horizontal line when the bridge is swung. The rule for constructing the curved tracks may also be expressed thus: A perpendicular line through the center of gravity, the center line of the swinging strut, and a line rectangular to the tangent of the curve intersect in one point for any position of the movable part. In consequence of this rule, the weight of the movable part and the two end reactions (compression in swinging strut and pressure on rollers) are in equilibrium for any position of the movable part. Diagrams of these three forces for the various positions are shown in Fig. 8 on the inset sheet. It will be observed that the maximum strains in the swinging strut and on the rollers occur in the closed position, and that the strains diminish going upward to a point marked 9; at this point the lower end of the main-girder finds a support on the pin-casting and in consequence the center of gravity, instead of following the above rule, describes the arc 9, 10 of a circle, and the movable part is supported only by the swinging strut and held in place by the operating machinery. This was done to relieve the rollers for inspection, oiling, etc.

The so-called inside main-girder was constructed as a plate girder for the rear panel carrying the track, and as a truss for the remaining two panels. The outside main-girder, being only two panels long, was constructed entirely as a plate-girder, its rear panel is a counter part to the inside main-girder, the second panel is of such depth as to be covered by the sidewalk planking.

In regard to the floor-system, special mention is to be made of the fact that there are two end floor-beams for the rear end, one marked "Q" attached to the inside main-girder and one marked "P" attached by stiff hangers to the outside main-girder. This construction was resorted to for the purpose of getting as nearly as possible equal loads on the two main-girders, the counter-weight being about equally distributed on the two. The amount of counter-weight required for one movable part is a little over 100,000 lbs., the total weight of one movable part is about 255,000 lbs., including the counter-weight.

Those familiar with the design of lift-bridges will readily see the advantage of the system in regard to counter-weight. All other existing types of lift-bridges (excepting those lifted vertically on towers) require such an amount of

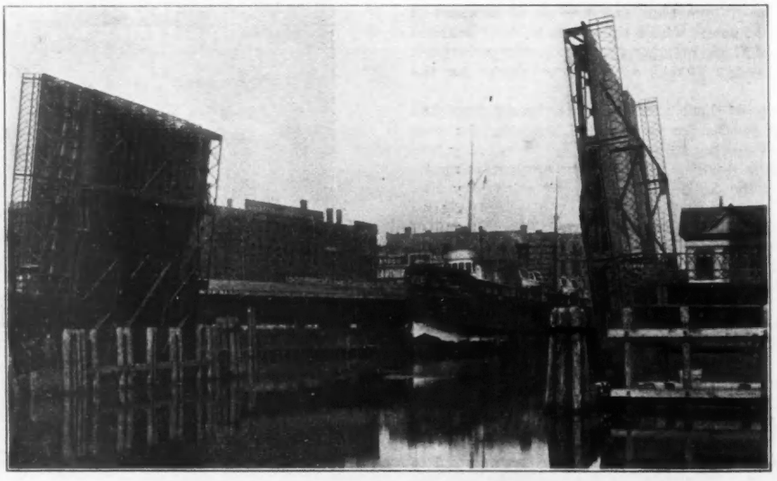


FIG. 2.—GENERAL VIEW OF HURON ST. LIFT BRIDGE; DRAW OPEN.

counterweight as to bring the center of gravity over the supporting masonry piers. In cases where the height of structure is limited this condition not only forms a difficult task for the designer, but also adds tremendously to the weight of the moving parts.

The operating machinery is of the simplest kind. The two inclined working struts are provided with steel racks, into which two pinions engage, mounted on the ends of the main shaft, which is 5½ ins. in diameter. The main-shaft carries a cast iron gear wheel 87 ins. in diameter, which is operated by a 9-in. pinion mounted on the 3¼-in. counter-shaft, which is driven by the gear of a 25 HP. Gibbs electric motor. The sheave for a band brake is also mounted on this shaft. For the motor-gear a standard cast iron street car gear was first used, but several breakages occurred, due to turning the power on in the wrong direction, by mistake, whereby it was shown that the wheel was not strong enough for the size of the motor. The gear was subsequently replaced by a steel wheel provided with a friction connection, and no trouble has been experienced since. A separate set of gearing for the purpose of operating the bridge by man power is provided and consists of a pinion engaging into the main gear wheel and turning a 3-in. shaft, which by a clutch can be connected to a set of gears operated by hand lever in the usual manner from the deck of the approach spans. The movable part is sufficiently locked by the machinery with the brake set on. As an additional safe-guard and for the purpose of locking when for some reason the brake is off, a locking arrangement, thrown in and out by the operator, is provided for.

The structure was erected without false-works. The stationary parts were first put up from shore by a boom derrick, which was afterwards shifted to the forward end of the approach-spans. The lift-spans, with floor-beams, stringers, etc., were erected in a upright position, as the channel had to be kept open all the time. After nearly all the iron work of the lift-spans, part of the counterweight and all parts of the machinery were in place, the bridge was lowered into its closed position, to receive the flooring and to be finished up otherwise, while always ready to be swung for a passing boat. The heaviest girder to be lifted by a boom derrick was 13,200 lbs.

The time of opening or closing the bridge by the motor ordinarily ranges between 25 and 35 seconds, the average being 30 seconds. The amount of power consumed is 9 to 10 electrical horsepower on an average, according to measurements taken by Messrs. Goltz & Sinclair, electricians, of this city. The amount of power, however, is materially increased when the bridge is to be swung against a strong wind, as it presents a large surface in the opened position. Since the day of opening for travel, Jan. 1, 1897, several heavy gales have occurred, and it was found that the motor had occasionally to be strained to its full capacity.

The contract for the entire superstructure was taken by the Milwaukee Bridge & Iron Works (the J. G. Wagner Co., Proprietors), at the price of $23,800. The engineer of the company, Mr. Fred Moore, and the Superintendent of the shop, Mr. J. Hahn, are to be especially commended for their faithful and competent execution of the work.

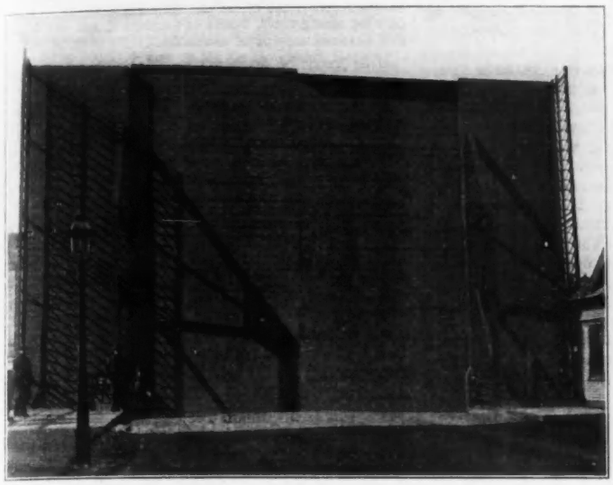


FIG. 3. VIEW OF RAISED LEAF OF DRAW FROM APPROACH.

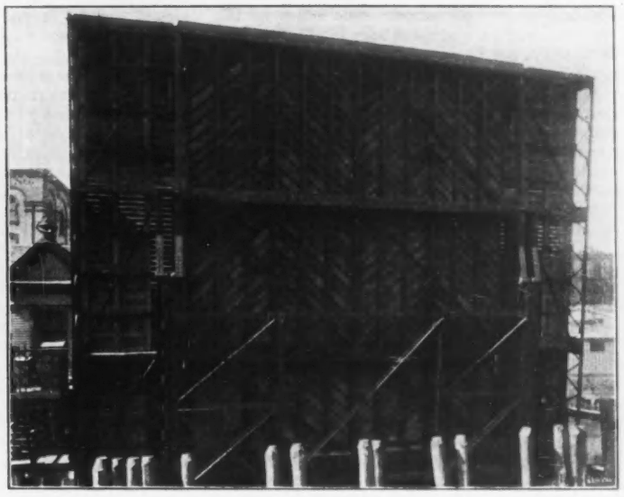


FIG. 4.—VIEW OF UNDER SIDE OF LEAF OF DRAW WHEN RAISED.

TESTS OF FIRE-PROOF FLOOR CONSTRUCTIONS.

In our issue of April 8 we described a test made by the Building Department of New York city to determine the resistance to fire and water of the system of fire-proof floor construction invented by Mr. R. Guastavino, 11 East 59th St., New York city. In that test the lower layer of tiles, which was set in Portland cement, not plaster of paris, as stated, was knocked off by the stream of water directed against it after the five hours' test by fire. The ceiling was repaired in 2¾ hours four days later, by covering about one-half of the ceiling with a coat of cement and by replacing on the other half the tiles that fell in the test. The fire and water test was repeated on April 15, with a load of 150 lbs. per sq. ft. on the roof, with the same results in all respects as those observed in the first test, some of the tiles of the lower and second courses and some of the cement coating being detached. This seems to prove that the floor was in no way damaged by the first test, except by the knocking off of the lower courses of tiles.

On April 19 a test was made at the same place, 68th St. and Avenue A, of the fire-proof flooring system of the Manhattan Construction Co., No. 156 5th Ave., New York city. This is one of the systems in which "expanded metal" is used to support a bed of Portland cement concrete. The building in which the test was made was one of those used in former tests of different floor constructions, 14×12 ft. inside dimensions and 12 ft. high above the double grates. The floor was divided into three 4×12-ft. panels by 9-in. beams. Resting on the bottom flange of these beams was a sheet of expanded metal, made of No. 10 sheet steel, the meshes forming diamond-shaped openings 3 ins. on each side. Concrete made of 1 part cement, 2 parts sand and 3 parts ashes was laid in a bed 3½ ins. thick, of which 1 in. was below the metal and 2½ ins. above. The space above this bed up to the level of the top of the beams was filled in with a weaker concrete of 1 part cement and 10 parts ashes. The under side of the beams was protected by wire netting enclosing a layer of plaster of about ½-in., and the whole ceiling was then plastered over with a coating about ½-in. thick. The central panel was loaded with pig iron to 150 lbs. per sq. ft. A fire was maintained under the floor, as in previous tests, for five hours. The maximum temperature, registered by the Uehling & Steinbart pyrometer, was 2,150° F. and for four hours it was 2,000° or above. The maximum deflection during the test was a trifle over 2 ins. At the end of the test a stream of water supplied by a fire engine, at a pressure of 60 lbs. per sq. in., was directed against the under side of the floor for 15 minutes and then water was poured on top of the floor till it was flooded. The effect of the stream was, as usual in similar tests, to dislodge the lower coatings of plaster and cement and to expose the metal supporting the upper portion, but no further damage was done. In the corners of the ceiling adjoining the door where the stream did not reach, even the lower coating of white plaster remained unharmed, indicating that whatever damage was done to the structure was done by the water and not by fire. After the floor had been cooled by water the deflection was found to have decreased to about 1 in. The result of the test was eminently satisfactory, and is additional evidence of the great resisting qualities of concrete floor construction, which has already been shown by the tests heretofore described in these columns.

On the same day, after completing the test of the floor, a highly interesting test was made of two wooden floor constructions. The first was a section 4 ft. square made of two thicknesses of ⅞-in. tongued and grooved yellow pine flooring, with a sheet of asbestos felt placed between. The second was an exactly similar section, with a layer of a kind of cement known as Merrill's patent "Salamander," made by the American Fire-Proofing Co., 166 Devonshire St., Boston, placed between the boards instead of the asbestos. The testing appar-

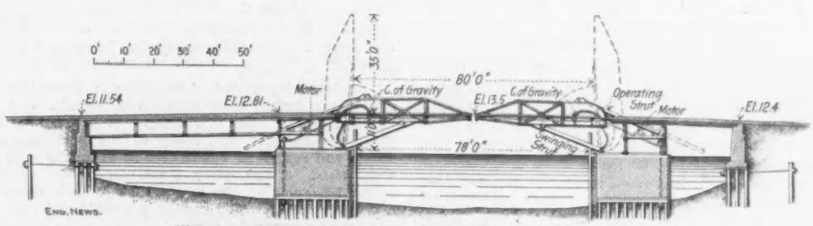


FIG. 5.—GENERAL ELEVATION OF HURON ST. LIFT BRIDGE.

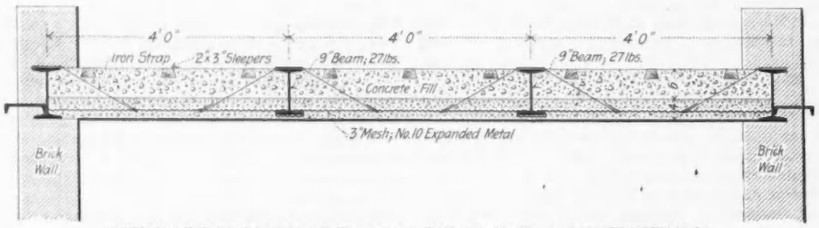
atus was designed by Mr. Stevenson Constable, Commissioner of Buildings, New York, N. Y., and consisted of a special furnace designed for the purpose, consisting of a trough or box of riveted sheet iron 9 ft. long, 5 ft. wide on top, tapering to 3 ft. wide at the bottom, and 2½ ft. deep. This was lined with 9 ins. of fire brick. The 4-ft. square section of flooring was used as a cover in the middle of the trough, and the ends were covered with corrugated sheet iron strips. The edges of the wooden flooring were all luted with sand. Fire was maintained in the box by two jets of crude oil, fed through steam jet oil burners, such as are used in burning petroleum under steam boilers. Steam at 50 lbs. pressure was supplied by a small vertical steam boiler. Temperatures were registered by the Uehling and Steinbart pyrometer, and also by a platinum-rhodium electric pyrometer, imported from Germany by Elmer & Amend, dealers in chemical apparatus, 18th St. and 3d Ave., New York city. At the beginning of the first test the furnace was cold and about 8 minutes were required to bring the temperature up to 1,000° F. It then rapidly rose to 1,500°, which was reached in 10 minutes more, and four minutes later the maximum temperature of 1,560° was reached. At 18 minutes from the start a very slight amount of smoke appeared at one of the joints in the flooring. At 27 minutes from the start cracks ¼ in. wide and 8 ins. long appeared in two places, and two minutes later flames burst through eight short cracks, when the test was ended and the floor removed. The lower layer was then almost entirely burnt away. In the second test, of the Salamander-lined flooring, the temperature for about five minutes rose more rapidly than in the first test, but by regulating the oil supply, according to the indications of the pyrometer, after 1,100° had been reached, the fire was kept in practically the same condition as in the first test. In 19 minutes from the start 1,500° was recorded; in 21 minutes, 1,550, and in 27 minutes, 1,625. At this time smoke was coming from several joints. In 28 minutes one of the cracks had blackened at the edges, and in 34 minutes a small tongue of flame came through. At 37 minutes flame was issuing through four joints, which gradually enlarged for three minutes more, or at 40 minutes from the start, when the test was ended and the floor removed in practically the same condition which the floor in the first test had reached in 29 minutes. The superiority of the Salamander lining over the asbestos lining was thus fairly proved, as it withstood a higher temperature and lasted a longer time than the latter.

On Tuesday, April 20, the tests of the American Fire-proofing Co.'s "Salamander" floor were continued, four samples of flooring of different composition being burned to failure. The first of these floors was made up of a bottom layer of ⅞-in. spruce and a top layer of ⅞-in. yellow pine, with two thicknesses of the "Salamander" between, or a little less than ⅛-in. The test started with the pyrometers recording 225°, and in 22 mins. a temperature of 1,500° had been reached. The temperature was then held between 1,500° and 1,600° during the remainder of the test. In 35 mins. smoke appeared through one crack, and others rapidly opened, until in 45 mins. about a dozen places were smoking. Flame appeared in 56 mins. from the beginning of the test. During the test the highest temperature reached was 1,650°, which occurred just before the flame burst through.

The second test was with four layers or about ¼-in. of "Salamander," with the same boarding as for the first test. As in the first test, also, the testing began with the pyrometers reading about 225°, and then the temperature was slowly raised to reach 1,500° in about 15 mins, and kept at about that degree. Smoke appeared through one of the cracks in 36½ mins., and the flames about ten minutes later, or 43½ mins. after the test began. In noting the comparatively poor showing of the four-ply sheeting as compared with the two-ply of the previous test, it needs to be stated that in the second sample of flooring the bottom course of spruce was of shaky boards, with several knotholes and crevices.

The third sample tested was the ordinary "mill floor" construction, namely, a bottom course of 2-in. tongued and grooved spruce planks, covered with a top course of ⅞-in. yellow pine, no "Salamander" being used. The heat was applied in all respects as in the previous tests. The first smoke showed in 63½ mins., and flame in 67½ mins. It was noticeable in this test that the burning was more uniform, but that the flame and smoke always first appeared between the joints, just over the joints of the bottom course of planks. When taken from the fire, in fact, it was shown that each of the tongued and grooved joints had opened up from 1 in. to 1½ ins., while the top course against the center of the planks had hardly been discolored by the fire. The lesson taught by this circumstance is obviously that the main weakness in the mill floor in resisting the passage of fire comes from the want of joint protection.

The fourth and last sample tested was the "mill floor" construction described for test No. 3, but with a single layer of "Salamander" between the courses. The conditions of the test otherwise were as previously described. The first smoke appeared in 62 mins. after the beginning of the test, and the flame broke through in 1 hr. 35 mins. from the beginning of the test. Five minutes later the flames were coming through at five different places. The previous remarks concerning the flames and smoke first appearing over the cracks of the bottom course of planks are true in regard to this test also. Altogether the special furnace used for conducting these tests worked very successfully.



SECTION OF THE FIREPROOF FLOOR OF THE MANHATTAN CONSTRUCTION CO.

NOTES FROM THE ENGINEERING SCHOOLS.

Purdue University, Lafayette, Ind., offers for the year beginning Sept. 15, 1879, eleven systematic courses in railway work, together with a series of lectures by eminent railway men upon subjects relating to their departments. Of the several courses, Nos. 1 to 4 inclusive are open to regular students in mechanical engineering; 5 to 8 inclusive to regular students in civil engineering, and 7 to 11 inclusive to all engineering students. All of these are open to graduate students. They are as follows:

1. Railway Equipment.—Locomotive construction and design, car design, train brakes and signals, and car lighting, heating and ventilating. 2. Locomotive Performance.—An analytical study of the performance of simple and compound locomotives as shown by road and shop tests. 3. Laboratory Work.—(a) Testing of locomotive Schenectady; also of Purdue's Baldwin compound locomotive engine. (b) Locomotive tests in series for the purpose of showing the effect of changes in the proportion of parts and of adjustment. (c) Tests of air pumps of the Westinghouse brake system, and of systems of car lighting. 4. Locomotive Design.—Drawing room practice. 5. Railway Surveying. 6. Railway Construction.—Cross sectioning, classification and computation of quantities, estimates, track laying, trestling, bridging, pile driving, pile foundation, culverts, bridge abutments and piers. 7. Economics of Railway Location.—Sources of income, operating expenses, effect of details of alignment, of gradients and curvature, and economy of construction. 8. Laboratory Work.—Tests of various elements common to railway construction, such as links, pins, turnbuckles, axles, channels, rails and rail joints; also tests of different constructive materials. 9. Railway Chemistry.—Applications of chemistry to railway interests; chemistry of iron and steel, fuels, water, lubricants and paints; chemical requirements in specifications. 10. Railway Economics.—Railway management, organization of railway departments, business administration of railways, railway rates, the railway and public opinion. 11. Railway Sanitation.—Sanitary conditions of railway cars and stations, preparation for emergencies, health of employees, and educational and financial aspects of sanitation.

University of Minnesota.—The College of Engineering, Metallurgy and Mechanic Arts has recently been separated into two colleges—that of Engineering and Mechanic Arts, including civil, mechanical and electrical engineering, and that of School of Mines, including mining and metallurgy. The dean of the former college, Prof. C. W. Hall, returns to the department of minerology in the College of Science. The new College of Engineering will hereafter confer the professional degrees of C. E., M. E. and E. E. upon its graduates.

Mr. E. E. Woodman, of the Chicago, St. Paul, Minneapolis & Omaha Ry., recently read a paper on "Modern Economics in Railway Management," before the Engineers' Society of the College of Engineering. These lectures by prominent engineers are given by the college as a regular feature of the term's work.

Stevens Institute of Technology.—There will be two vacancies in the American Railway Master Mechanics' Association Scholarships at the close of the present college year in June. Sons of members of the Association who are eligible for these scholarships, and who desire to attend the preliminary examinations, should apply to Mr. John W. Cloud, Secretary, Rookery Building, Chicago, and, if found eligible, he will give a certificate to that effect for presentation to the school authorities, which will entitle the candidate to attend the preliminary examinations. These examinations will begin at the Institute on June 4 and continue until June 10. When it is desired, the school authorities will arrange for the examination of an applicant at any of the large cities of the country.

Lehigh University.—A system of combined literary and scientific courses is announced by this institution, as follows:

The authorities of the University, being convinced that many men who desire eventually to study a technical profession would appreciate a preliminary literary education, have decided to offer to such persons an opportunity of combining culture studies with those which belong to practical life. Any student who wishes to do so will be permitted to substitute such technical studies as are approved by the faculty, for a portion of the regular work of the Junior and Senior years. At the end of the four years he will receive the literary degree appropriate to his course. If he then chooses to complete the technical course to which the substituted studies belong he can do so, and may expect to receive the technical degree in from one to two years, depending upon the course chosen and the diligence of the student. This opportunity will be valuable to many who may have use for the technical knowledge which may be acquired within the four years, even where they are unable to remain for the full technical course; while to those who can avail themselves of the combined courses it offers a means for acquiring a well-rounded training which will fit them for more effective work and for greater success in the future.

University of Nebraska.—The state legislature has appropriated $30,000 for the wing of a building, which is to be used by the College of Mechanic Arts of the University.

AN APPARATUS FOR AUTOMATICALLY plotting topographical sections has been patented by Messrs. Chas. W. Smith and Ellis B. Noyes. As described by the inventor, Mr. Noyes, and illustrated in the patent, this work is performed by the revolution of a road-wheel with suitable gearing for reducing to any scale and plotting the results on a continuous sheet of profile paper, so far as changes in the vertical plane are concerned. Changes in level are recorded by a pendulum-wheel of peculiar construction; but space forbids going into the illustrations necessary for a clearer understanding of the apparatus and its operations. As to the uses to which it is to be applied, the inventor says that, on a scale of 40 ft. to 1 in., it will be sufficiently accurate for nearly all topographical work, or for state surveys and a large amount of public land surveys. On a scale of 10 ft. to 1 in. he proposes to use the apparatus for making cross-sections of earth work for monthly estimates, made on the same sheet month by month. Mr. Noyes is desirous of finding some one who will sufficiently interest himself in this device to assist him in having the machine made on a full working scale, and he solicits correspondence on this subject directed to him at 409 Middle St., Portsmouth, Va.